PB86-244845

Report on the Survey of Abandoned Uraniferous Lignite Mines in Southwestern North Dakota

(U.S.) Office of Radiation Programs
Las Vegas Facility, NV

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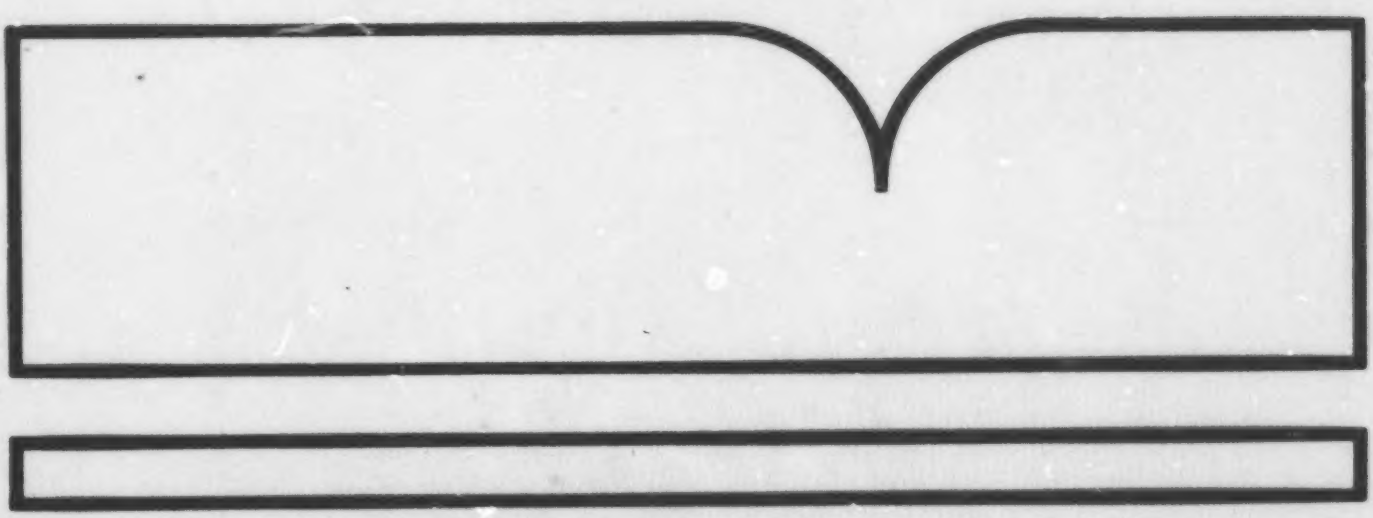

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TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA 520/1-86-013		PB86 244845/AS

4. TITLE AND SUBTITLE	5. REPORT DATE
Report on the Survey of Abandoned Uraniferous Lignite Mines in Southwestern North Dakota	April 1986
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) R. J. Lyon, D. Prochaska, J. L. Burgess and D. Patrick	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Radiation Programs-Las Vegas Facility P.O. Box 18416 Las Vegas, Nevada 89114	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency 401 M Street S. W. Washington, D.C. 20460	13. TYPE OF REPORT AND PERIOD COVERED
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Radiation measurements were made and soil samples were taken at approximately 300 locations around six mine sites comprising eleven lignite mine pits. Toxic element analysis was also done on 50 of the soil samples. The general radium-226 background in the area (4.2 pCi/gm) is affected by uranium ore outcroppings and is approximately four times the average background (1.2 pCi/gm) of radium-226 content. Concentrations of radium-226 ranged from 1.0 to 250 pCi/gm for all the soils sampled.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Lignite Mines Uranium Contamination		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release Unlimited	Unclassified	59
	20. SECURITY CLASS *(This page)*	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

United States
Environmental Protection
Agency

Office of
Radiation Programs
Washington, D.C. 20460

EPA 520/1-86-013
August 1986

PB86-244845

Radiation

EPA

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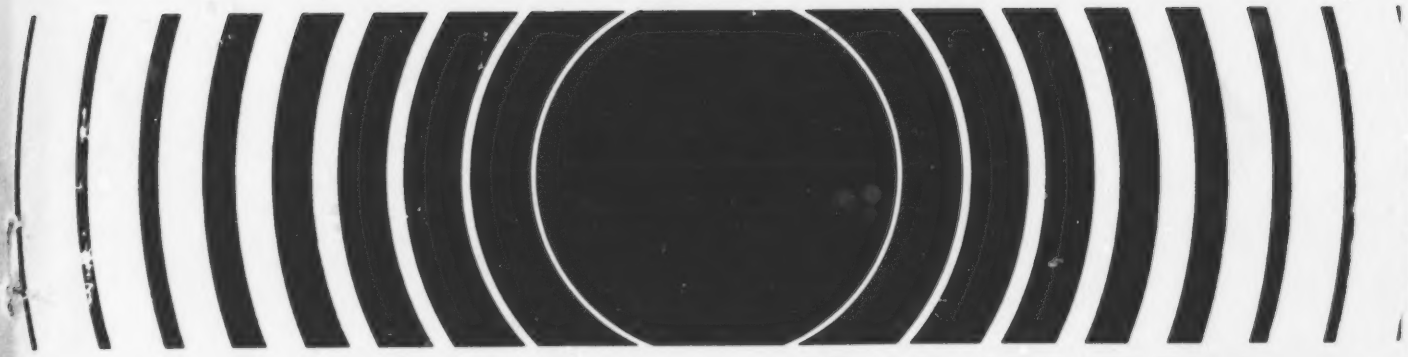

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REPORT ON THE SURVEY OF ABANDONED URANIFEROUS LIGNITE MINES IN SOUTHWESTERN NORTH DAKOTA

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March 1986

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FOREWORD

The Office of Radiation Programs (ORP) of the U.S. Environmental Protection Agency (EPA) carries out a national program to evaluate population exposure to ionizing and nonionizing radiation and to promote the development of controls necessary to protect the public health and safety.

Within the Office of Radiation Programs, the Las Vegas Facility (ORP-LVF) conducts in-depth field studies of various radiation sources (e.g., nuclear facilities, uranium mill tailings, and phosphate mills) to provide technical data for environmental impact assessments as well as information on source characteristics, environmental transport, critical pathways for population exposure, and dose model validation. The ORP-LVF also provides, upon request, technical assistance to Western States and to other Federal agencies. The ORP-LVF conducted a radiological survey of abandoned uraniferous lignite mines in southwestern North Dakota. This survey was done with the assistance of the North Dakota State Department of Health and EPA's Region 8. Results, analysis, and recommendations for cleanup are included in this report.

Readers of this report are encouraged to inform the ORP-LVF of any omissions or errors. Comments or requests for further information are also invited.

Sheldon Meyers

Sheldon Meyers, Director
Office of Radiation Programs

ABSTRACT

A radiation survey was conducted in October 1983 as part of the proposed reclamation plan of abandoned uraniferous lignite mines in southwestern North Dakota. This survey was made to determine the extent of contamination caused by mining operations in the 1960's. Radiation measurements were made and soil samples were taken at approximately 300 locations around six mine sites comprising eleven lignite mine pits. Toxic element analysis was also done on 50 of the soil samples. This information is needed in order to estimate the area around the pits which should be decontaminated during reclamation operations. The general radium-226 background in the area (4.2 pCi/gm) is affected by uranium ore outcroppings and is approximately four times the average background (1.2 pCi/gm) of radium-226 content. Concentrations of radium-226 ranged from 1.0 to 250 pCi/gm for all the soils sampled. Although several samples taken near the edges of some pits had radium-226 concentrations in excess of 50 pCi/gm, in general the soil samples taken near the pits were in the range of 10-20 pCi of radium-226 per gram of dry soil. Based on the toxic element analysis, there does not appear to be a potential risk from these elements at the mine sites. If the standards for remedial actions at inactive uranium processing sites are applied to this reclamation operation, an area of approximately 130 acres and a volume of 110,000 cubic yards will be disposed of or controlled.

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ACKNOWLEDGEMENTS

We would like to acknowledge the assistance of the following people on the survey part of this study.

John Giedt	EPA, Region 8
Steve Charlton	North Dakota State Department of Health
Rodney Peterson	North Dakota State Department of Health
Edith Boyd	EPA, Office of Radiation Programs-LVF
Joseph Hans	EPA, Office of Radiation Programs-LVF
Paul Wagner	EPA, Office of Radiation Programs-LVF

We would also like to acknowledge the analytical assistance of Milton Lammering, Chief, Analytical Support Branch, EPA, Denver, Colorado.

SUMMARY AND CONCLUSIONS

In April 1983, the North Dakota State Department of Health in conjunction with the North Dakota Public Service Commission requested technical assistance, cleanup, decommissioning guidance and equipment from EPA to proceed in a joint effort to plan for and reclaim six uraniferous lignite mine sites (eleven pits).

In October 1983, approximately 300 locations around lignite pits were surveyed. Measurements of external gamma exposure were made with pressurized ionization chambers (PIC) and scintillometers. Soil samples from most locations were taken for gamma spectral analyses. Radon exhalation measurements were made at about 30 locations at two mine sites.

A very good correlation of scintillometer and PIC measurements was found. Soil radium content and scintillometer reading correlations were also very good. There appeared to be no correlation between radium concentration in soil and radon exhalation from the soil.

The analyses of soil for toxic metals indicate no health hazard from these elements.

The mean background level of radium-226 in soil was 4.2 pCi/g dry soil which is higher than the U.S. average of 1.2 pCi/g. Thirty percent of the soil samples were in the background range of 1-6 pCi/g. Seventy percent of the samples indicated contamination from the lignite mines. If the standards for remedial action at inactive uranium processing sites are applied to this reclamation operation, approximately 110,000 cubic yards of soil will be disposed of or stabilized.

INTRODUCTION

In the mid 1960's, uraniferous lignite was suface mined for its uranium content at several sites in southwestern North Dakota. The ore was burned in or near the lignite pits, or ashed at nearby rotary kilns. The ash was then shipped to mills in New Mexico, South Dakota, and Colorado for processing.

The rotary kiln sites at Bowman and Belfield, North Dakota, have been designated by the Department of Energy (DOE) as inactive uranium processing sites and are deemed eligible for the Uranium Mill Tailings Remedial Action (UMTRA) Program. Since the mine sites did not have mechanical processing equipment such as the rotary kilns at Bowman and Belfield, DOE has decided that they are not eligible for the program even though ashing (upgrading or beneficiation) was done in open pits.

In 1979 representatives of the North Dakota State Department of Health (SDH) and the Office of Surface Mining obtained limited water, soil, and vegetation samples as well as gamma radiation measurements from the mining and ashing sites. This cursory environmental survey indicated varying degrees of contamination.

In mid-1980 the North Dakota Public Service Commission (PSC) was notified by the Office of Surface Mining that the abandoned uraniferous lignite mines were considered eligible for discretionary funds for reclamation. The Howie site was selected as a pilot reclamation project because it is located on State-owned land. Extensive preliminary radiation surveys were made by the North Dakota State Department of Health in conjunction with the Environmental Protection Agency's (EPA's) Office of Radiation Programs-Las Vegas Facility (ORP-LVF). The site was reclaimed by

Dickinson State College, under contract to the Public Service Commission (PSC), making limited use of the suggestions and recommendations of the State Health Department and EPA. Aesthetic reclamation appears to have been successful; however, post reclamation survey results indicate elevated radiation levels.

In September of 1982, the North Dakota PSC and the State Department of Health entered into a contract for the performance of radiation surveys at six abandoned uraniferous lignite mines in North Dakota. In April 1983, the North Dakota State Department of Health formally requested technical assistance, cleanup and decommissioning guidance, and equipment from EPA to proceed in a joint effort to plan for and reclaim these six mine sites (11 pits).

In July 1983, an aerial radiological survey of the uraniferous lignite mines was conducted by EG&G for the EPA (C184). The aerial photographs were used as a basis for the ground survey. The photographs are included herein as Appendix A.

In October 1983, approximately 300 locations around the uraniferous lignite pits were surveyed by measuring external gamma exposure, soil sampling, or both. Follow-up sampling in November 1983 and April 1984 resulted in additional gamma measurements being made as well as soil sampling. A total of approximately 1000 gamma exposure measurements and 300 soil samples were taken to better define the extent of contamination.

METHOD

SAMPLING PROCEDURE

The aerial radiological survey of the lignite mine sites done under contract by EG&G in July 1983 revealed extensive ore outcroppings (C184). Because of this, the usual survey procedure around uranium mine and milling operations was modified (Do75) to account for expected ore outcroppings.

The following measurements were made at various points around the lignite pits:

1. Scintillometer measurements at three feet above ground level, at ground level (open shield), and at ground level (closed shield) (D075).
2. Pressurized ion chamber (PIC) measurements at three feet above the ground.
3. Soil samples were taken at most of the points at which scintillometer measurements were made.
4. Charcoal canisters used to measure Rn-222 exhalation were placed sparingly at two separate mine sites.

Gamma exposure readings with NaI (TI) scintillometers were taken starting at the edge of each pit. (Number and directions of radials were determined for each pit at the time of the survey, see below for numbering system.) The crystal of the scintillometer was then shielded with a lead shield. If the difference between the readings was 5 μR/hr or greater, a soil sample was taken. Most soil samples were taken to a depth of 15 centimeters with a golf course auger. A right cylinder soil sample 8 cm in diameter and 15 cm in length was obtained. Another gamma exposure reading was taken at a point 100 feet from the pit edge in the direction of the radial. In general, measurements were taken and soils sampled at 100-foot intervals going away from the pit edge in the eight compass directions: north, south, east, west, northeast, southeast, northwest, and southwest directions. The sampling continued outward until the difference between the closed-shield and open-shield gamma measurements was 5 μR/hr or less. The last or outermost soil sample on any given radial around a pit was to represent the background levels around that pit. (See Figure 1 for graphic description of the survey plan.)

Identification of Radials and Sampling Locations

In order to specifically identify the sampling locations for each lignite pit, the following identification system was devised. The appendixes contain raw data using this identification system.

Each sampling location is identified by a six-digit number. The first three digits signify the approximate compass direction and the radial. The second three digits signify the distance away from the pit in 100-foot intervals.

For each pit, the northern-most radial is numbered 010.... The number increases in a clockwise direction; the total number of radials varies with each pit. For example, Smith B pit has just four radials: 010..., 020..., 030..., and 040.... In contrast, Fritz pit has sixteen radials: 010..., 020..., 030..., 040..., 050..., 060..., 070..., 080..., 090..., 100..., 110..., 120..., 130..., 140..., 150..., and 160.... (Fritz pit also has two radials on which duplicate samples were taken and these radials are labelled with the original radial number and a "1" in the third spot to signify a duplicate. These two radials are labelled 041... and 051...).

For each radial on each pit, the sampling location is identified as to distance from the pit edge. For example, on Smith B pit, the northern-most radial is labelled 010... and has four sampling locations:

1. 010000 (at the pit edge)
2. 010001 (100 feet from the pit edge)
3. 010002 (200 feet from the pit edge)
4. 010003 (300 feet from the pit edge)

Therefore, when referring to the raw data in the appendices it is easy to identify the approximate direction and location from each pit for each sample.

At a limited number of locations (six or seven at each pit) a PIC measurement was made at locations where scintillometer measurements were also made. PIC measurements were used as the criterion to validate the scintillometer measurements and to obtain true gamma exposure rate measurements.

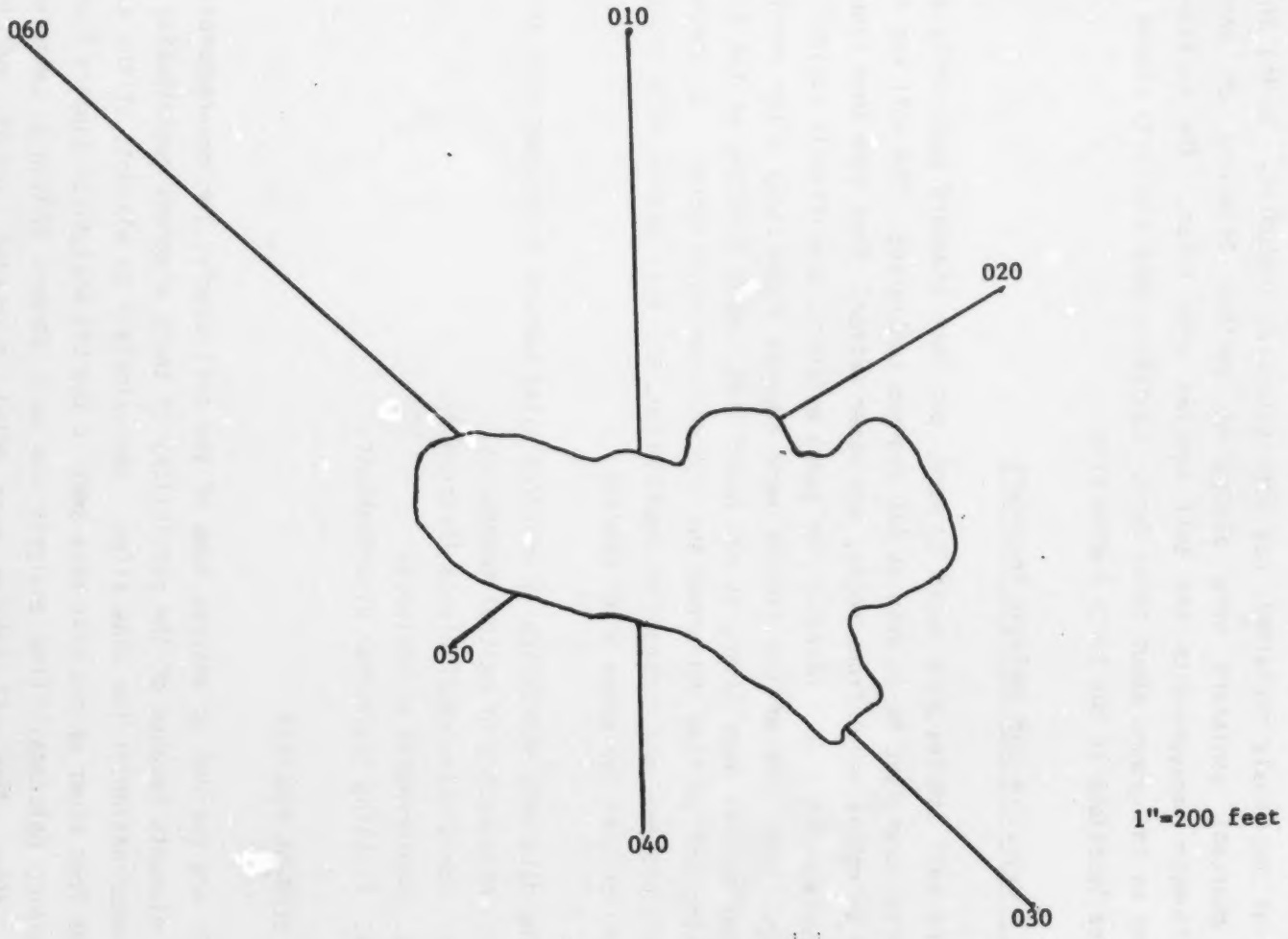


Figure 1. Smith mine site (West pit).

Two mine sites were used to measure Rn-222 exhalation. The Howie mine, which was previously reclaimed, has been extensively studied. During this study charcoal canisters were placed at various locations at which scintillometer measurements and soil samples were taken. The canisters remained on the ground about three days. Canisters were similarly placed at selected locations at the Smith A mine site.

Sample Preparation and Analysis Procedure

The soil samples were mixed by hand, put into standard tuna cans, and then dried overnight in an oven at 110 degrees centigrade. The soil was not sifted to remove vegetation, rocks, and other matter. They were then canned and counted with a GeLi detector for gamma emitters, specifically radium-226 progeny. When some of the samples were counted immediately after canning and then several days later, it was noted that simple handling of the soil by mixing and pouring disturbed the radium/radon equilibrium. To correct for this problem, and reestablish equilibrium, all soil samples were counted not earlier than two weeks after canning.

The data were statistically analyzed using various techniques such as:

1. Measurement of central tendencies.
2. Correlation coefficients (Pearson r).
3. Measurements of variance.
4. Plotting log-normal distributions.

TOXIC ELEMENT ANALYSIS

It was decided to analyze some of the soil samples for non-radioactive toxic elements because of the possibility of these elements contributing to the contamination at the mine sites. Approximately 50 aliquots of the soil samples from eight of the pits were sent to the EPA Analytical Support Branch in Denver, Colorado. (The analysis was done through Milton W. Lammering, Chief, ASB). The soil samples were dried, quartered, ground, put into solution, and analyzed for toxic elements such as arsenic, molybdenum, and

lead. The data are tabulated in Appendix B. Although heavy metals or toxic elements are present in measurable amounts, the non-radioactive elements do not present a health hazard (ACGIH 84).

RESULTS AND DISCUSSION

DETERMINATION OF BACKGROUND LEVELS

The contamination levels around the pits are based on radium-226 content of soil to a depth of 15 cm. The radium-226 background in soil was difficult to define due to the abundant uranium ore outcroppings in the area of the mine sites. If the unshielded scintillometer measurement at the ground was less than 30 μR/hr and the difference of the shielded and unshielded measurement was less than 5, the sample was considered background. The average background for the United States is 1.2 pCi Ra-226 per gram (EPA83). A background radium-226 concentration of 4.2 pCi is estimated per gram of dry soil near the mine sites. Approximately 30 percent of the soil samples were considered to be background based on these values. Background sample data are tabulated in Appendix C. Also, Figure 2 is a frequency distribution of all background samples.

The Standard (40CFR192) for cleanup for inactive mill tailings states that remedial action should be conducted so that the radium-226 concentration averaged over 100 square meters shall not exceed background level by more than 5 pCi/g averaged over the first 15 cm of soil below the surface. If these guidelines were applied to the North Dakota lignite mine sites, the cleanup area should include sampling locations with radium-226 concentrations greater than 9.5 pCi/g of soil.

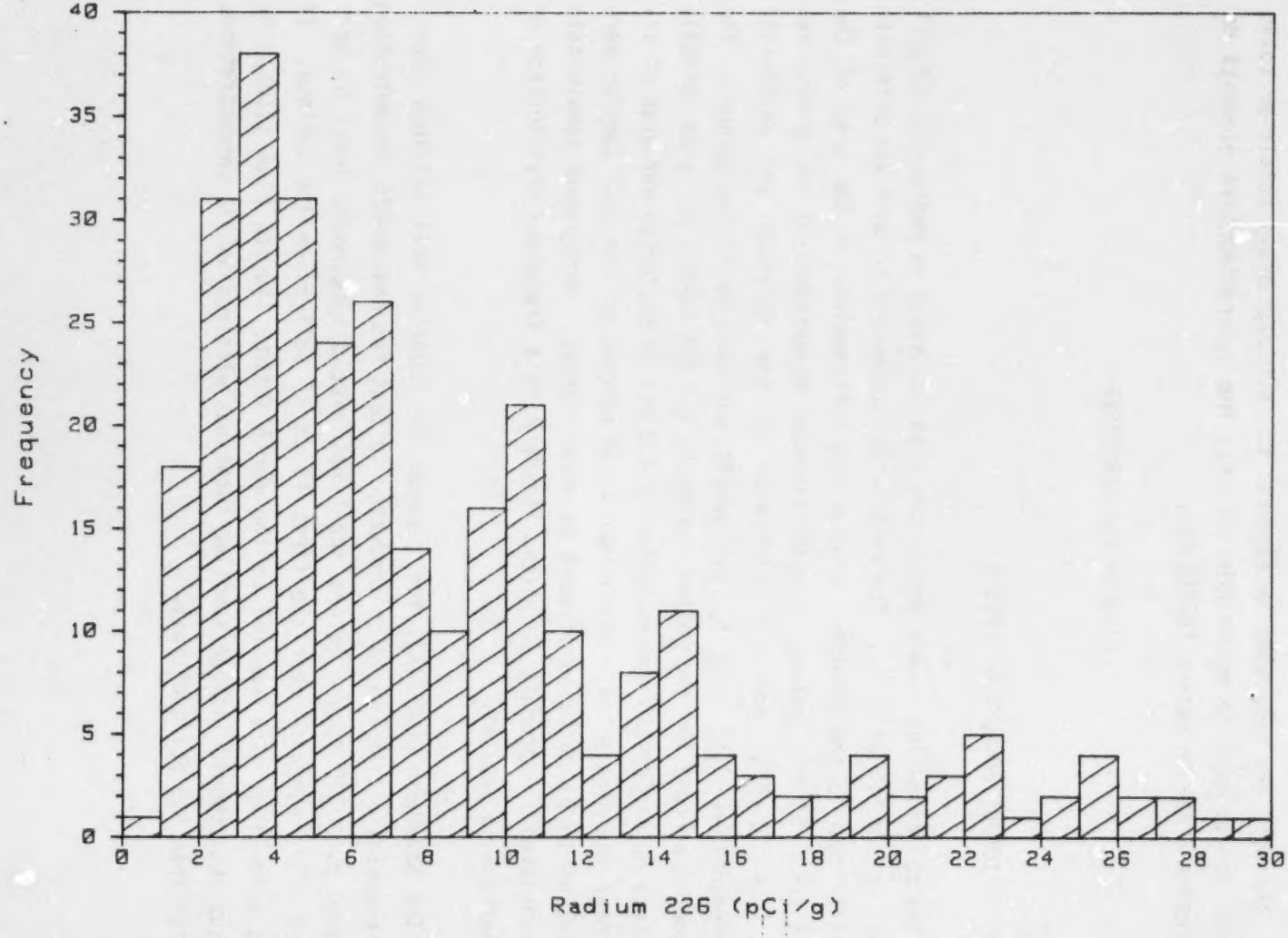


Figure 2. Frequency distribution of background samples.

EXHALATION MEASUREMENTS

Table 1 compares Ra-226 concentration in soil to Rn-222 exhalation at that location. Figure 3 shows the lack of correlation between these measurements. This is in part due to the non-uniformity of the contamination.

TABLE 1. Rn-222 EXHALATION AND Ra-226 IN SOIL

Smith A Radial	Ra-226 (pCi/g dry soil)	Rn-222 (pCi/m^2 sec)	Howie Radial	Ra-226 (pCi/g dry soil)	Rn-222 (pCi/m^2 sec)
010000	39.9	10.3	020002	9.1	7.2
010001	6.9	9.1	020004	13.0	5.0
010002	6.8	15.5	020006	27.6	9.1
030000	12.9	4.5	020008	29.7	45.1
030001	7.8	7.6	020010	23.0	9.6
030002	5.4	5.8	020012	10.9	9.5
030003	4.4	2.5	020014	3.9	2.1
040000	15.0	2.3	040000	20.0	11.6
040001	2.9	1.5	040002	22.3	8.0
040002	2.2	2.8	040004	33.7	16.6
			040006	4.3	3.3
			040007	6.4	2.1
			040008	4.5	9.6

VALIDATION AND ADJUSTMENT OF SCINTILLOMETER MEASUREMENTS

Although the contamination survey and soil sampling were based on scintillometer measurements, these measurements needed to be corrected to provide external gamma exposure. Eighty-four pressurized ion chamber (PIC) measurements were made for this reason. The scintillometer reading can be converted to gamma exposure using the equation:

$$\mu R/hr = 0.48 \times \text{Scintillometer Measurement at 3 feet} + 4$$

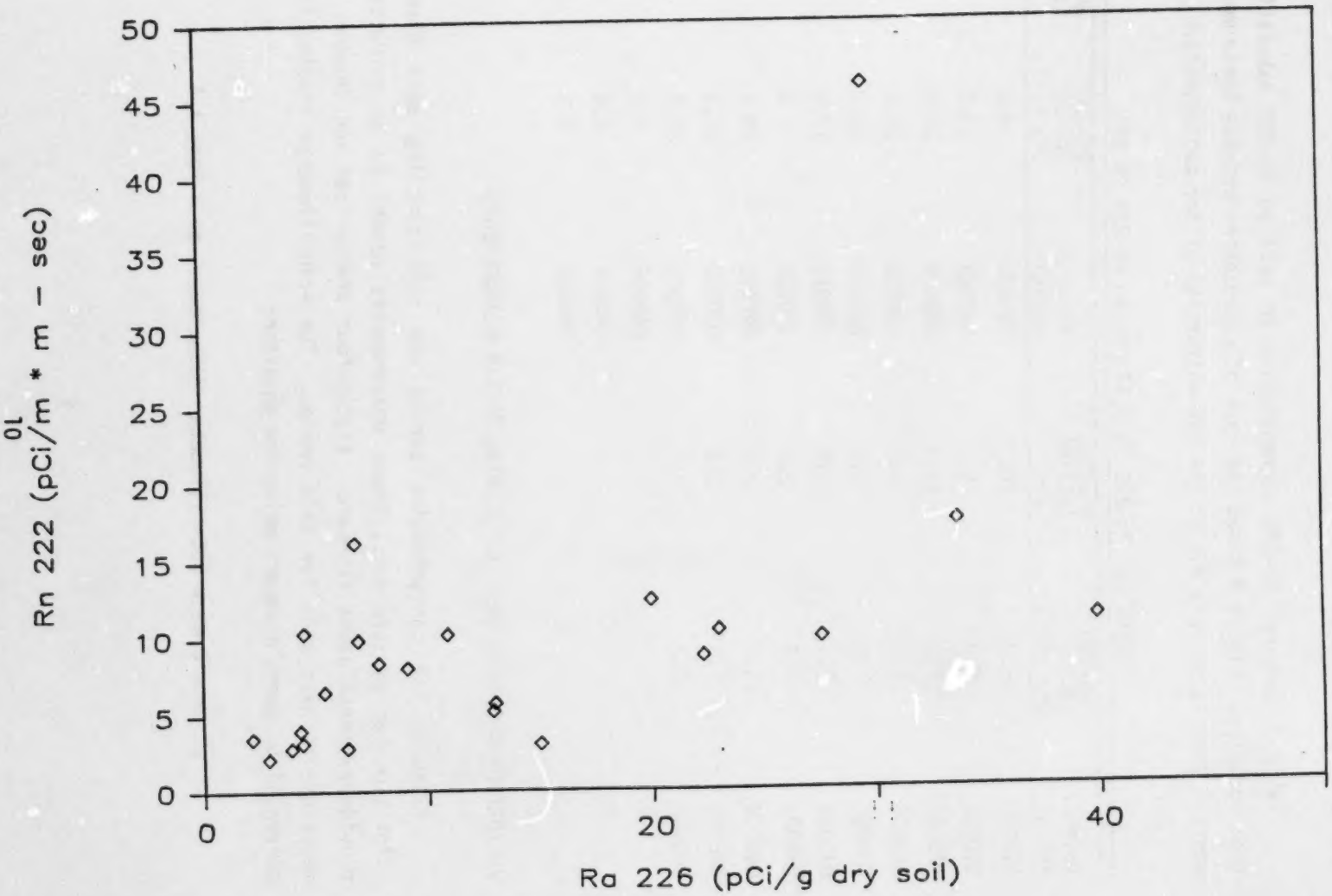


Figure 3. Correlation of Ra-226 concentrations and Rn-222 exhalation.

A correlation between the PIC and scintillometer measurements at three feet was calculated to be 0.96 (see Appendix D).

The radium-226 concentrations in the soil were also correlated with the scintillometer measurements. The radium-226 concentration and the delta value correlated 0.92, while the radium-226 concentration and the scintillometer ground (open shield) measurement correlated 0.91. The equations to convert the scintillometer measurement to radium concentration are:

$$\text{Ra-226 (pCi/gm)} = 1.18 \times \text{Delta Measurement} - 0.50 \text{ and}$$

$$\text{Ra-226 (pCi/gm)} = 0.49 \times \text{unshielded ground scintillometer measurements} - 6.12$$

FRACTIONATED SAMPLES

In order to determine depth of contamination, several fractionated soil samples were taken at the following depths: 0-5 cm, 5-10 cm, and 10-15 cm. The Ra-226 concentrations of these fractionated samples are included as Appendix E. It is clear from these results that contamination due to Ra-226 is generally found in the first five centimeters of soil.

ASSESSMENT OF MINE SITE CONTAMINATION AND CLEANUP

Four of the six mine sites (Palaniuk, Talkington, Frank, and Klym) are located north of Belfield, North Dakota, and two sites (Smith and Fritz) are south of Belfield. The areas and volumes of contaminated soil have been calculated based on the application of the inactive mill tailings standards. Appendix F contains the Ra-226 data for non-background samples. Figure 4 is a frequency distribution of the Ra-226 concentrations in soil samples except those in excess of 31 pCi/g. Figure 5 is a frequency distribution of the Ra-226 concentrations in all soil samples.

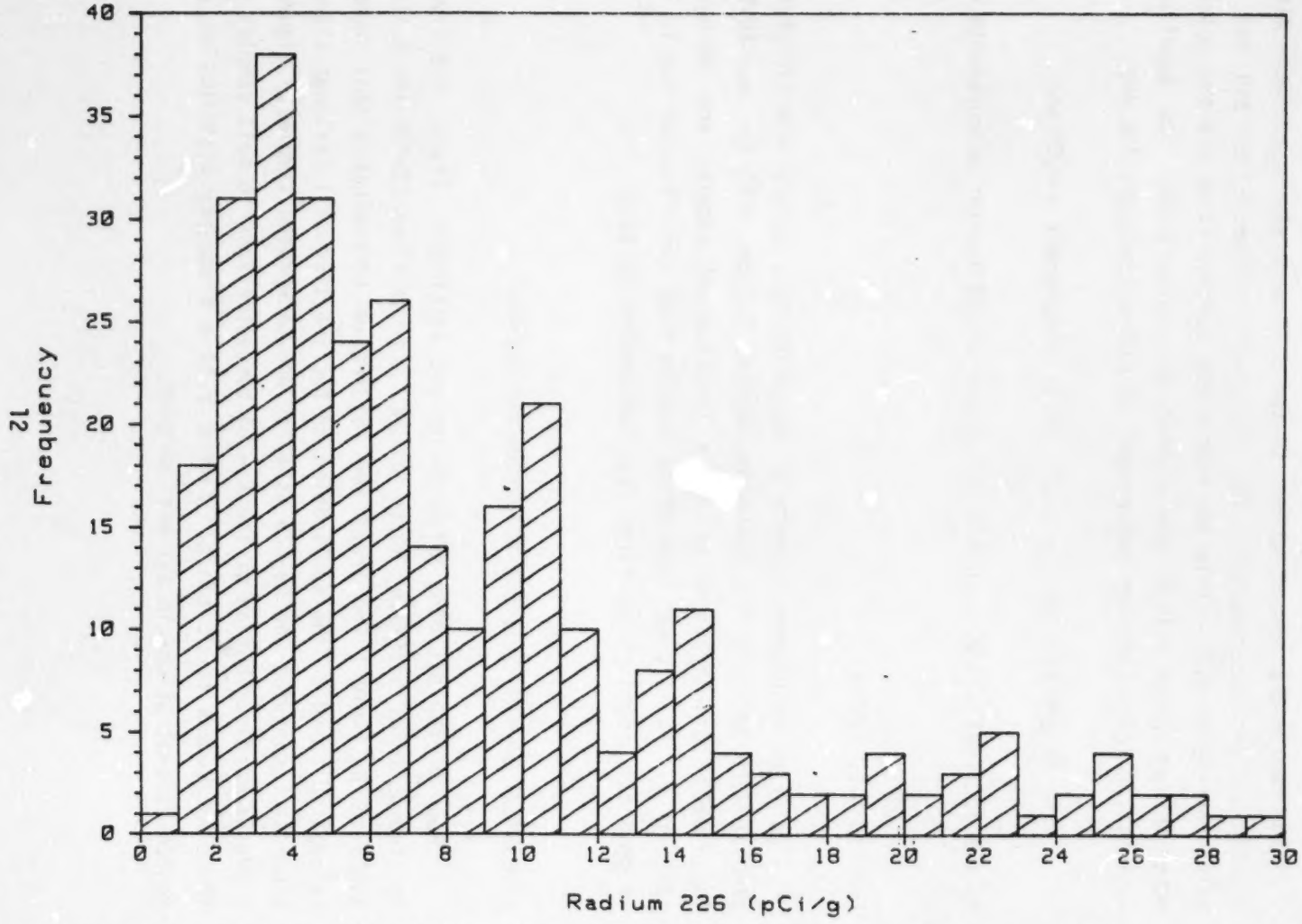


Figure 4. Frequency distribution of Ra-226 concentrations in soil up to 31 pCi/g.

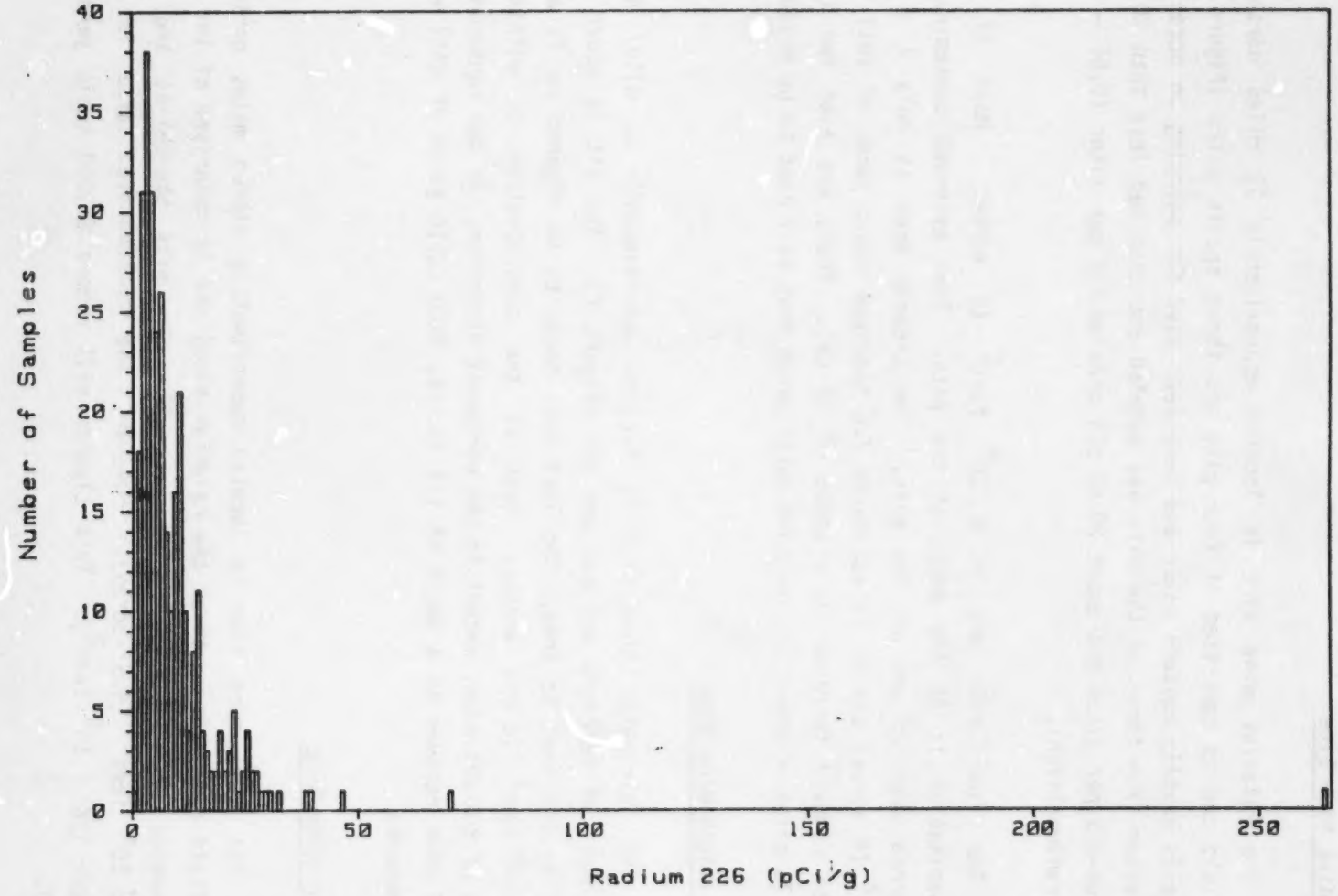


Figure 5. Frequency distribution of Ra-226 concentrations in all soil samples.

Palaniuk Mine Site

The Palaniuk mine site is located approximately 12 miles north of Belfield and is comprised of four pits and three spoils piles (Figure 6). The pits usually contain water and have been used for swimming on occasion. The water from three of the pits was sampled and each had less than 20 pCi radium-226 per liter and about 20-80 pCi uranium-234 per liter (0.06 - 0.25 mg uranium/liter).

The four pits are 4×10^5 feet^2 (9 acres). Most of the contamination is at the edges of the pits. Some extended contamination occurred west of one of the pits. The cleanup area is only 4×10^5 feet^2 (9 acres) and it is estimated 7.6 thousand cubic yards of soil need to be removed (scraped to a depth of 15 cm). There are also two large spoils piles of about 150 thousand cubic yards that will need to be moved.

Talkington Mine Site

The Talkington mine site is located approximately 12 miles north northwest of Belfield and has one pit (Figure 7). The pit is about 1500 feet by 500 feet in area. The land that needs to be cleaned up is about 3×10^5 feet^2 (6 2/3 acres). Most of the contamination is within 50 feet of the pit edge, except in the northwest direction. If the contaminated soil were removed to a depth of six inches, 5400 cubic yards of soil would be removed.

Frank Mine Site

The Frank mine site is located approximately eleven miles north of Belfield (one mile south of the Palaniuk site) and is comprised of two pits separated by a county road (Figures 8). The pits themselves are only 20×10^5 feet^2 (4.5 acres). However, the contaminated area is much larger (36×10^5 feet^2). This cleanup will remove 67,000 cubic yards of soil.

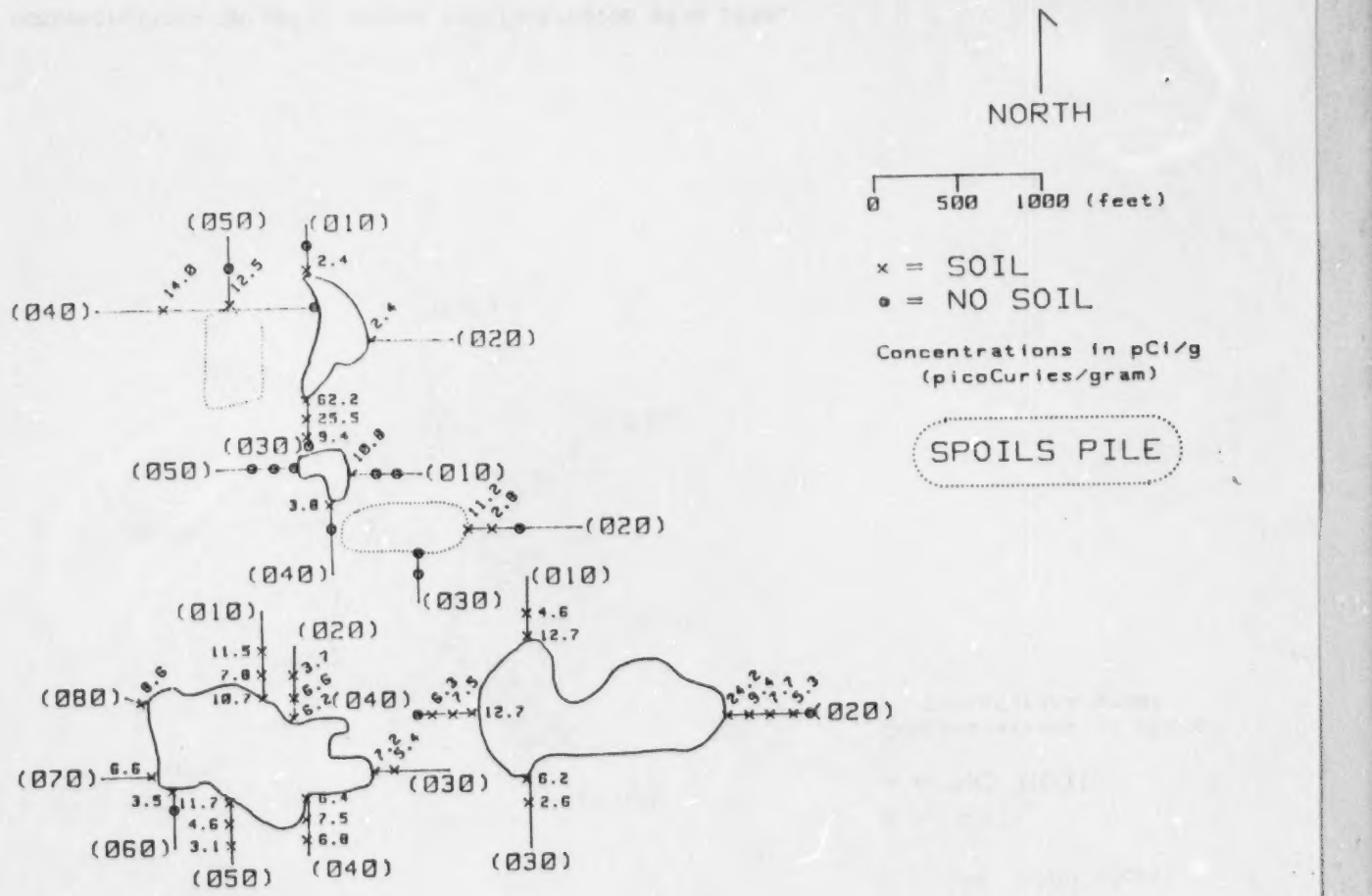


Figure 6. Ra-226 concentrations in soil around the Palaniuk mine site.

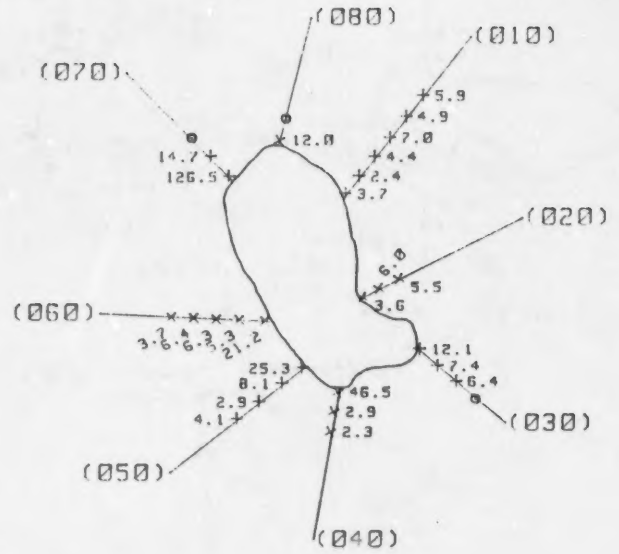


Figure 7. Ra-226 concentrations in soils around the Talkington mine site.

Klym Mine Site

The Klym mine site is located approximately 14 miles north-northeast of Belfield (Figure 9). The site has two pits; however, since they are separated by only a dirt road, they can be considered a single mine. The pit measures 2500 by 1250 feet. Most of the contamination lies within 50 feet of the pit edge. A large area just east of the pit is contaminated and contains a spoils pile. The area of contamination around the pit is 6×10^5 feet^2 (14 acres), and about 11,000 cubic yards of soil should be removed.

Smith Mine Site

The Smith mine site is located approximately 12 miles south of Belfield and is comprised of two small pits (Figure 10). The smallest pit (east of the large pit) is not contaminated. In fact, it has lower radium concentrations than the general area background. The larger pit shows contamination at the pit edge or within 50 feet of the edge with the exception of the area northwest of the pit. In the northwestern direction contamination is evident out to 550 feet from the edge of the pit. The cleanup area is 2×10^5 feet^2 (4.6 acres) which requires the removal of 3900 cubic yards of soil.

Fritz Mine Site

The Fritz mine site is located approximately 18 miles south of Belfield and is the largest pit surveyed (Figure 11). The pit is 4500 feet long and 1700 feet wide; however, contamination around the pit is limited to the eastern edge. The contaminated area is 7×10^5 feet^2 requiring removal of 13 thousand cubic yards of soil.

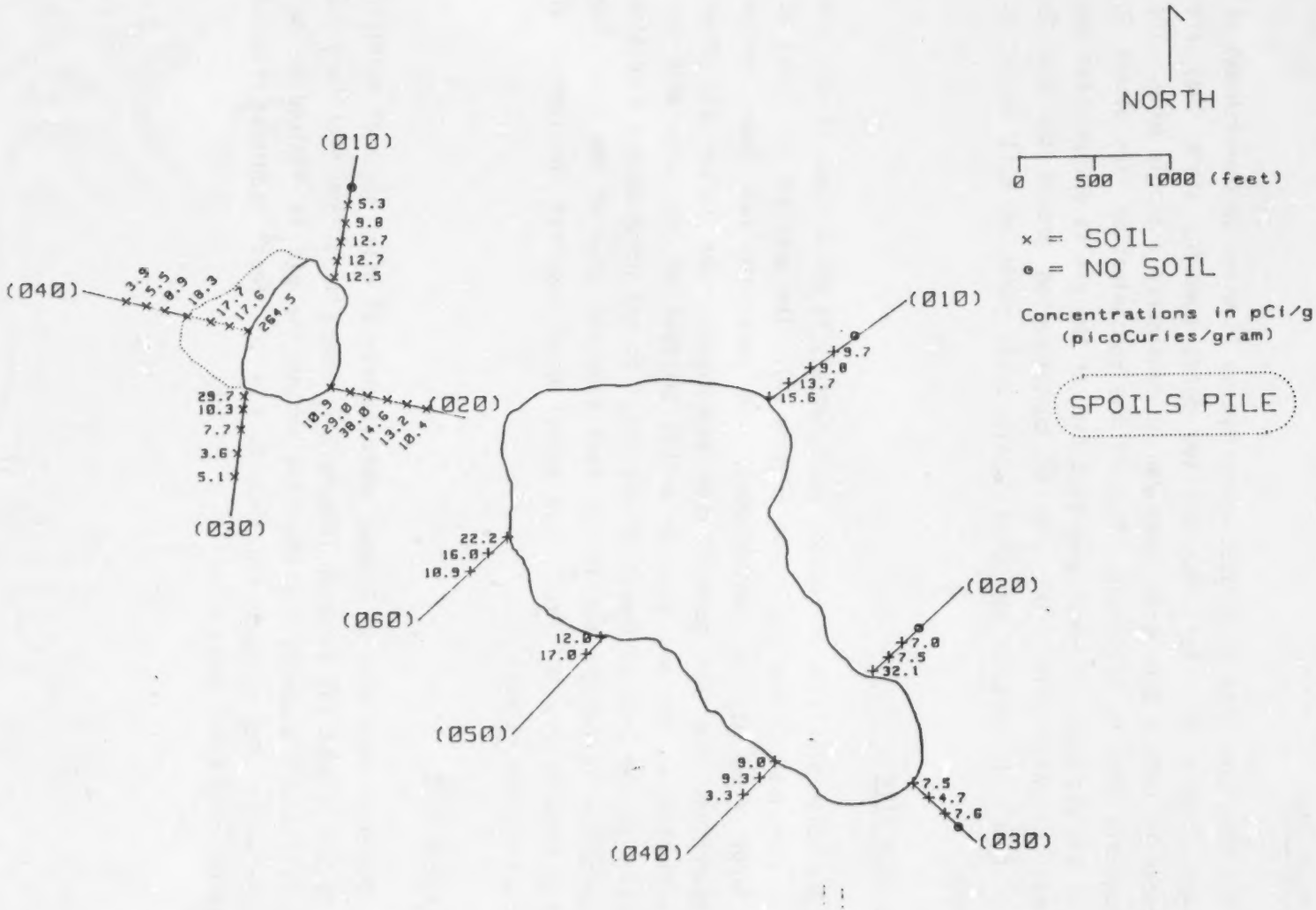


Figure 8. Ra-226 concentrations in soils around the Frank mine site.

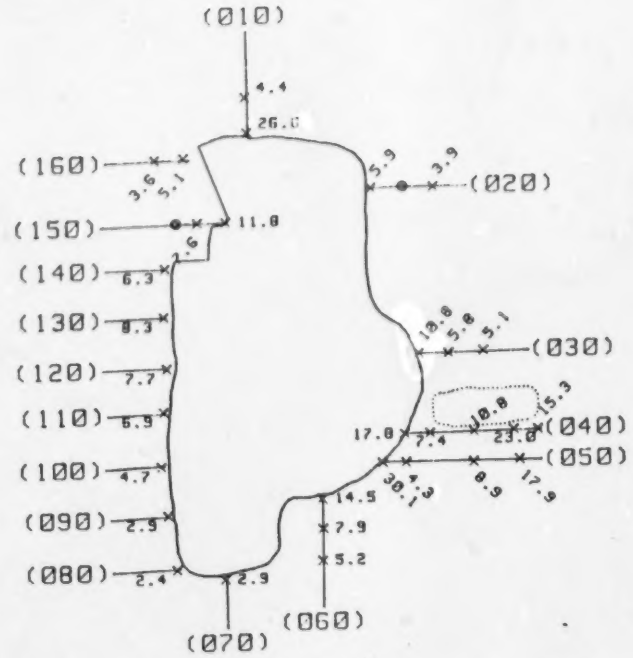


Figure 9. Ra-226 concentrations in soils around the Klym mine sites.

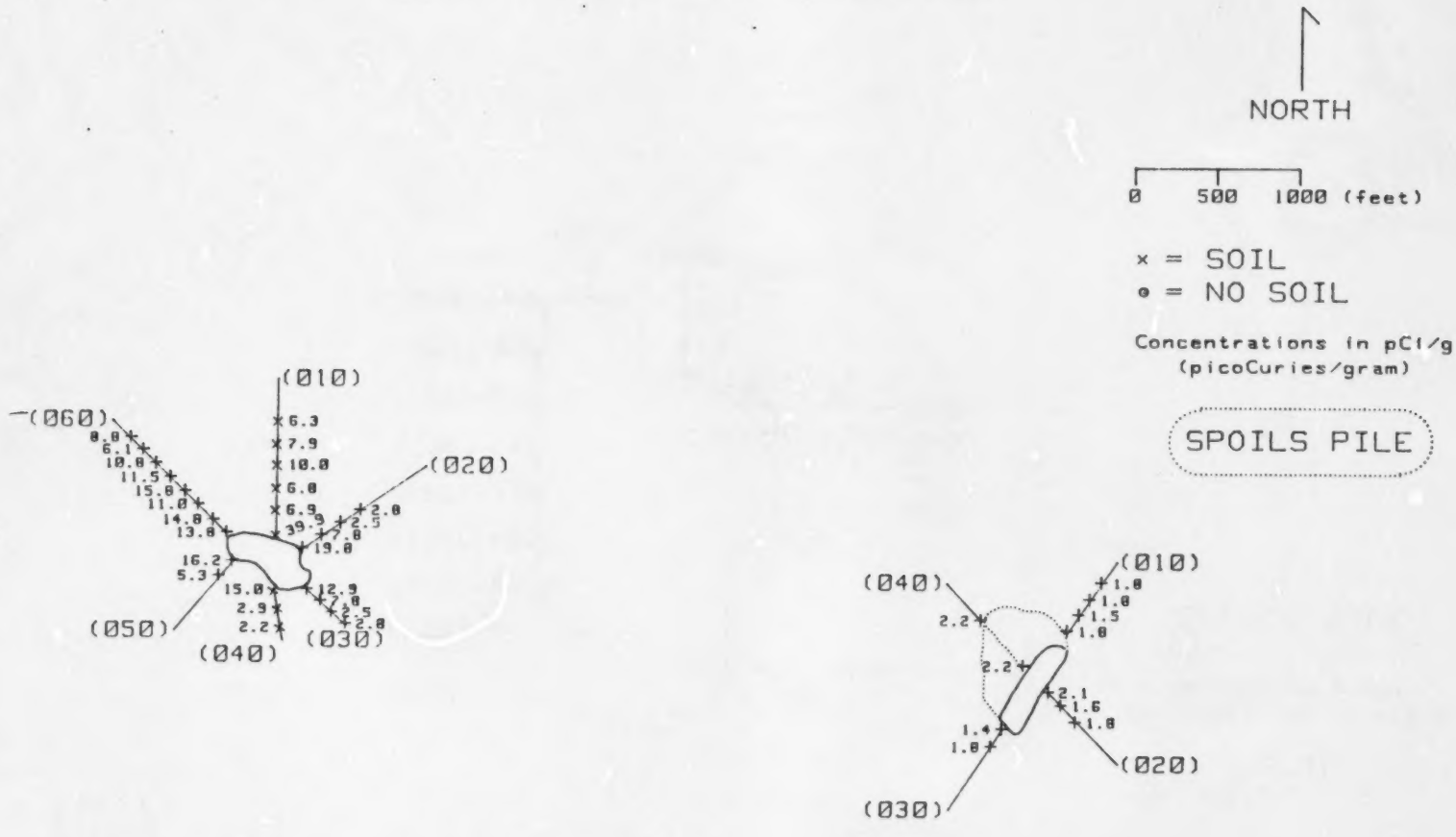


Figure 10. Ra-226 concentrations in soils around the Smith mine site.

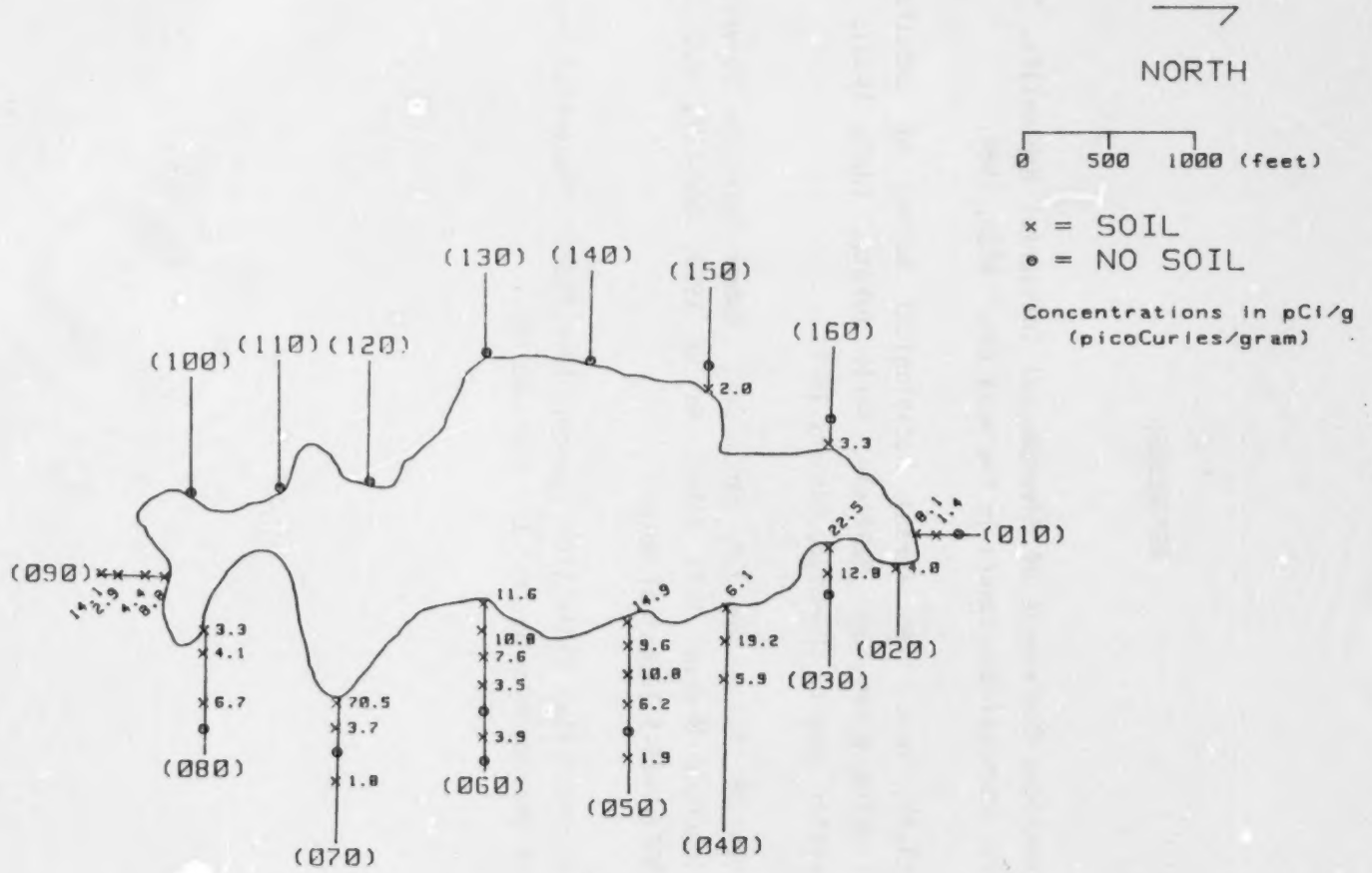


Figure 11. Ra-226 concentrations in soils around the Fritz mine site.

REFERENCES

(ACGIH84) American Conference of Governmental Industrial Hygienists, "TLVs for Chemical Substances in the Work Env," ACGH, 1984.

(C184) Clark, H.W., An Aerial Radiological Survey of Uraniferous Lignite Mines Near Belfield, North Dakota, (July 1983), EG&G Letter Report, EPA-8402, January 1984.

(D075) Douglas, R.L., and J.M. Hans, Jr., Gamma Radiation Surveys at Inactive Uranium Mill Sites, August 1975, ORP-LVF, U.S. EPA, ORP/LV-75-5 Technical Note.

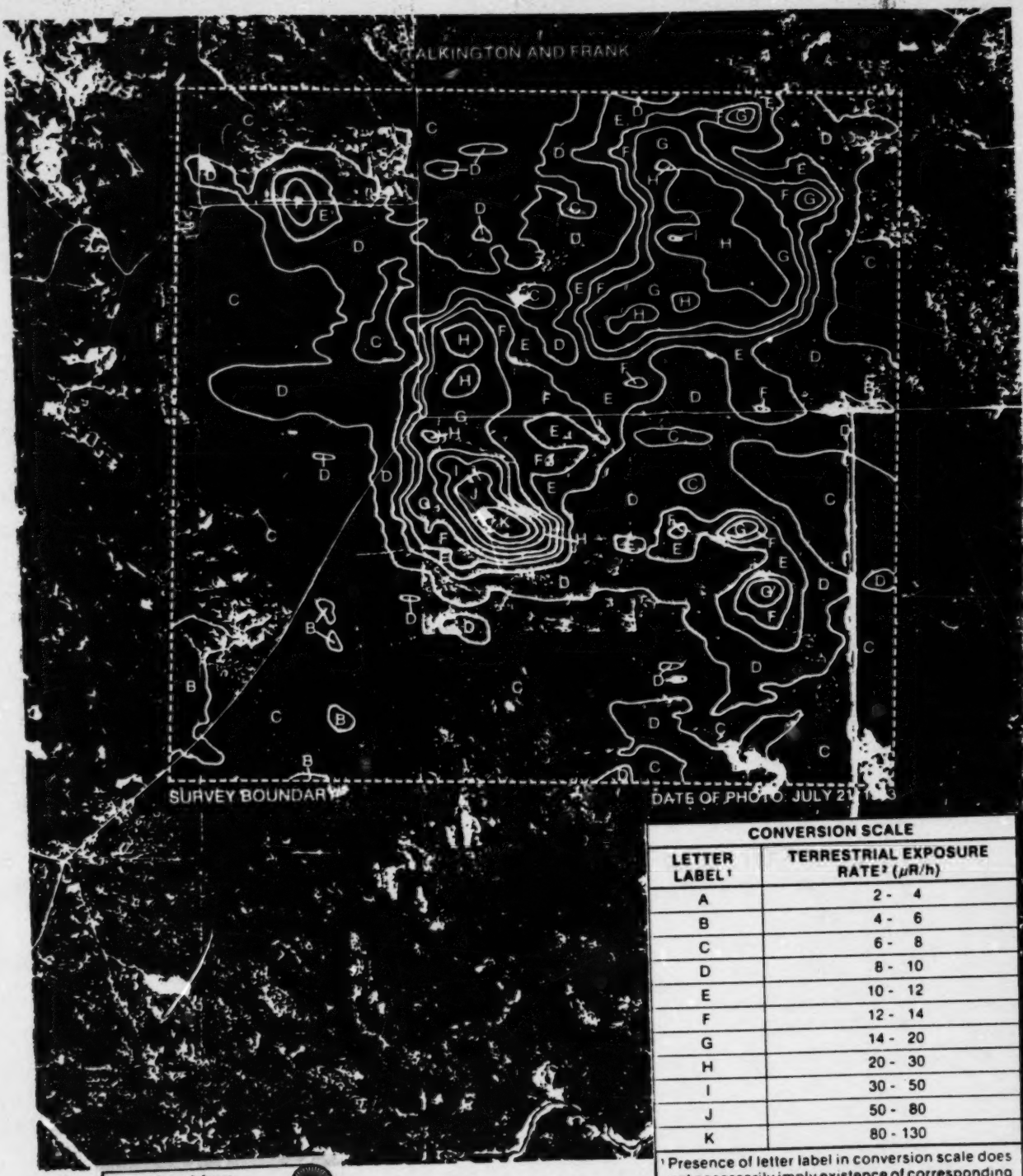
(EPA83) Environmental Protection Agency, June 1983. "Potential Hazards of Uranium Mine Wastes" EPA 520/1-83-007.

APPENDIX A

AERIAL PHOTOGRAPHS

Aerial photographs were taken of eight uraniferous lignite mine sites near Belfield, North Dakota, in July 1983. The aerial radiological surveys were conducted for the EPA by EG&G and DOE.

The aerial surveys were done to "map the spatial extent and degree of contamination due to mining operations and to document the natural radiological environment surrounding these sites." (C184, p1). This appendix contains the aerial photographs and superimposed isoradiation contours of terrestrial gamma ray exposure for the mine sites. For a detailed description and methodology involved in creating these photographs and isoradiation contours, please see the publication by H.W. Clark listed in the references.



CONVERSION SCALE	
LETTER LABEL[1]	TERRESTRIAL EXPOSURE RATE[2] (μR/h)
A	2 - 4
B	4 - 6
C	6 - 8
D	8 - 10
E	10 - 12
F	12 - 14
G	14 - 20
H	20 - 30
I	30 - 50
J	50 - 80
K	80 - 130

[1] Presence of letter label in conversion scale does not necessarily imply existence of corresponding contour interval in plot.

[2] Contours indicate gamma exposure rate extrapolated to 1 m above the ground, inferred from gamma count rate observed at 75 ft above the ground. Extrapolation valid only over large areas comparable to the detector's field-of-view. Cosmic rays contribute an additional 4.4 μR/h to the reported values.

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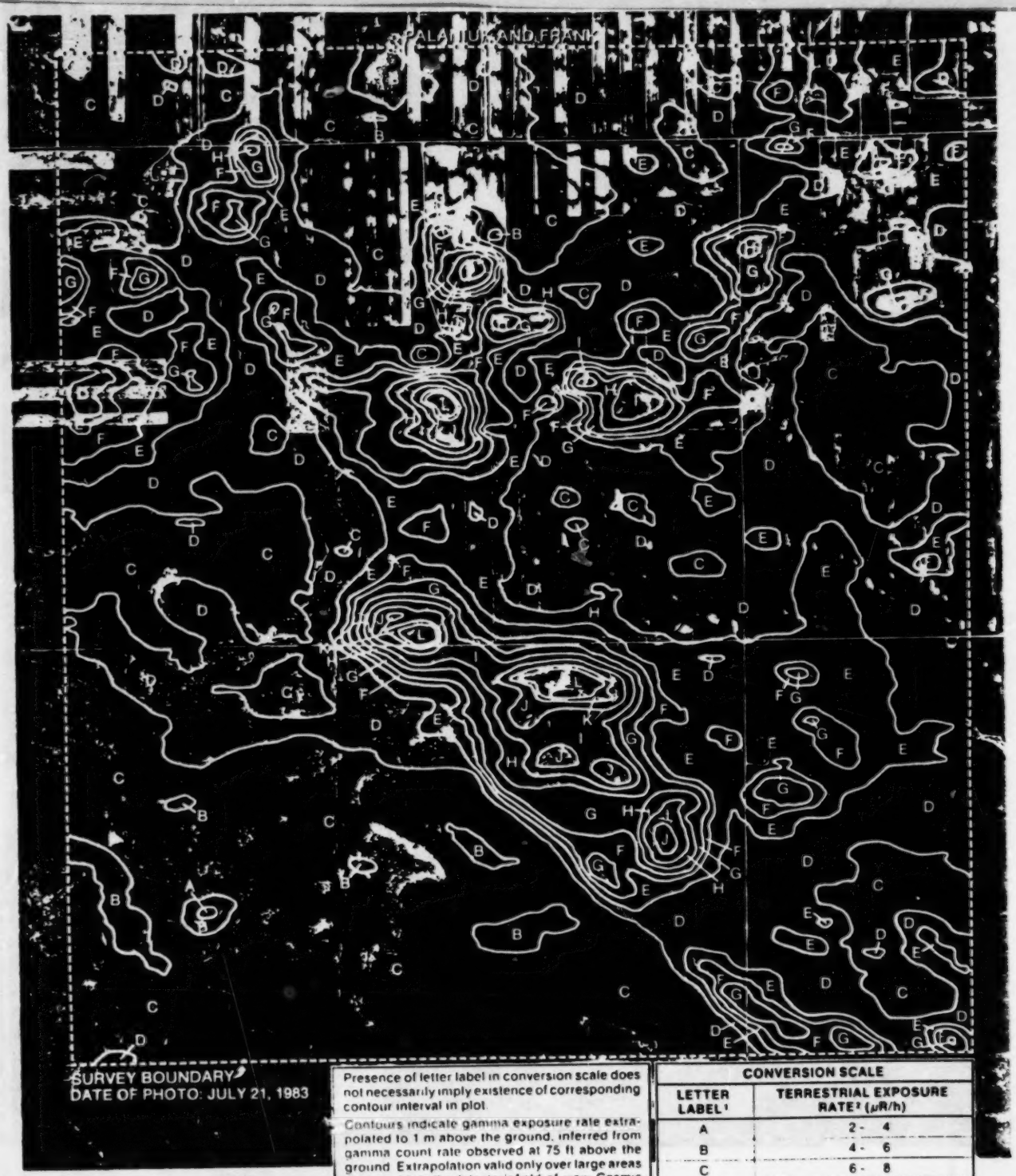
N

0 1000 2000 3000 FEET

0 200 400 600 800 1000 METERS

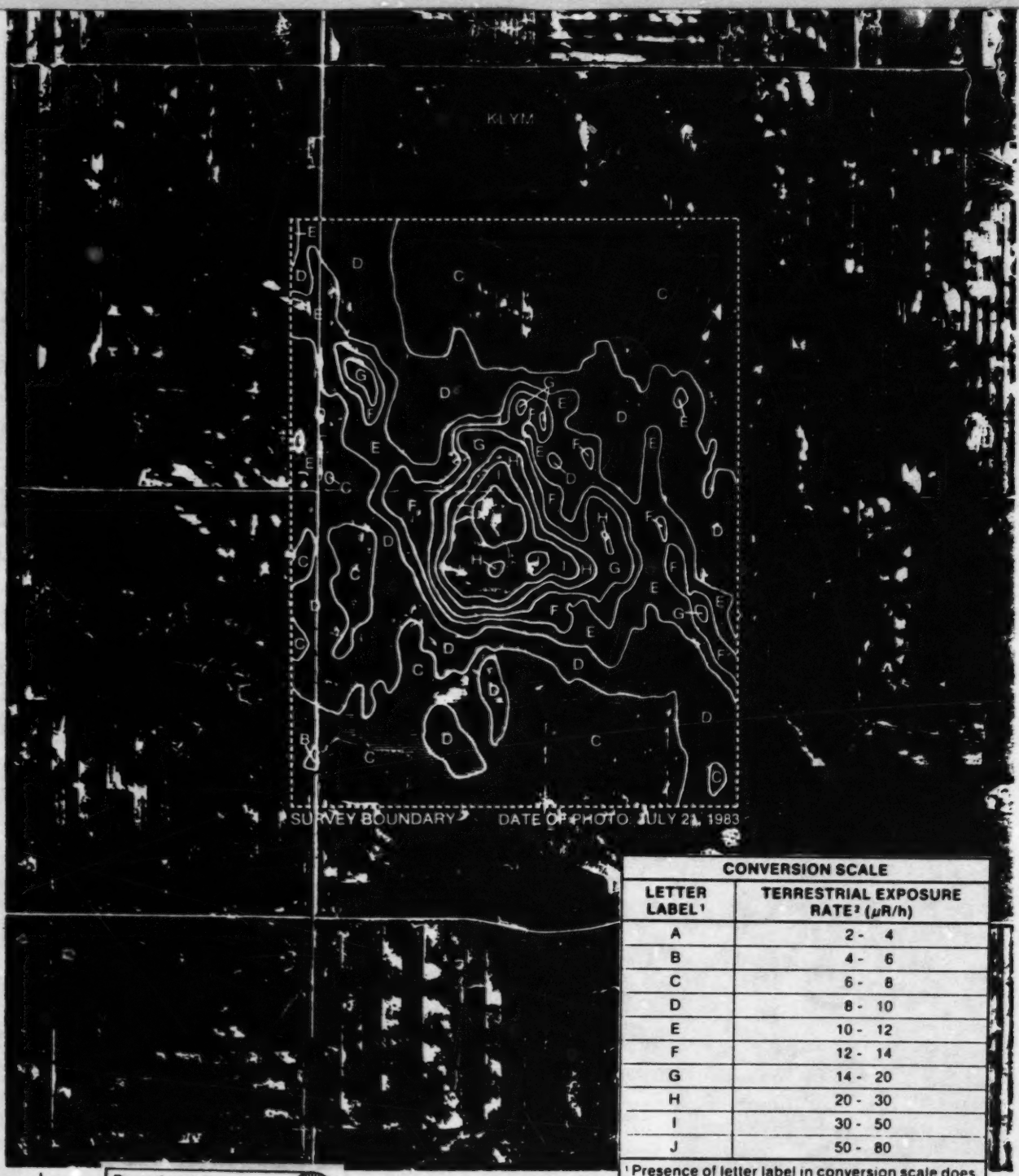
ISORADIATION CONTOURS OF TERRESTRIAL GAMMA RAY EXPOSURE RATE SUPERIMPOSED ON AN AERIAL PHOTOGRAPH OF THE TALKINGTON AND FRANK URANIFEROUS LIGNITE MINE SITES NEAR BELFIELD, NORTH DAKOTA (T140-R100-S10)



CONVERSION SCALE

LETTER LABEL[1]	TERRESTRIAL EXPOSURE RATE[2] (μR/h)
A	2 - 4
B	4 - 6
C	6 - 8
D	8 - 10
E	10 - 12
F	12 - 14
G	14 - 20
H	20 - 30
I	30 - 50
J	50 - 80
K	80 - 130
L	130 - 200

ISORADIATION CONTOURS OF TERRESTRIAL GAMMA RAY EXPOSURE RATE SUPERIMPOSED ON AN AERIAL PHOTOGRAPH OF THE PALANIUK AND FRANK URANIFEROUS LIGNITE MINE SITES NEAR BELFIELD, NORTH DAKOTA (T140-R99-S6,7)



CONVERSION SCALE	
LETTER LABEL[1]	TERRESTRIAL EXPOSURE RATE[2] (μR/h)
A	2 - 4
B	4 - 6
C	6 - 8
D	8 - 10
E	10 - 12
F	12 - 14
G	14 - 20
H	20 - 30
I	30 - 50
J	50 - 80

[1] Presence of letter label in conversion scale does not necessarily imply existence of corresponding contour interval in plot.

[2] Contours indicate gamma exposure rate extrapolated to 1 m above the ground, inferred from gamma count rate observed at 75 ft above the ground. Extrapolation valid only over large areas comparable to the detector's field-of-view. Cosmic rays contribute an additional 4.4 μR h to the reported values.

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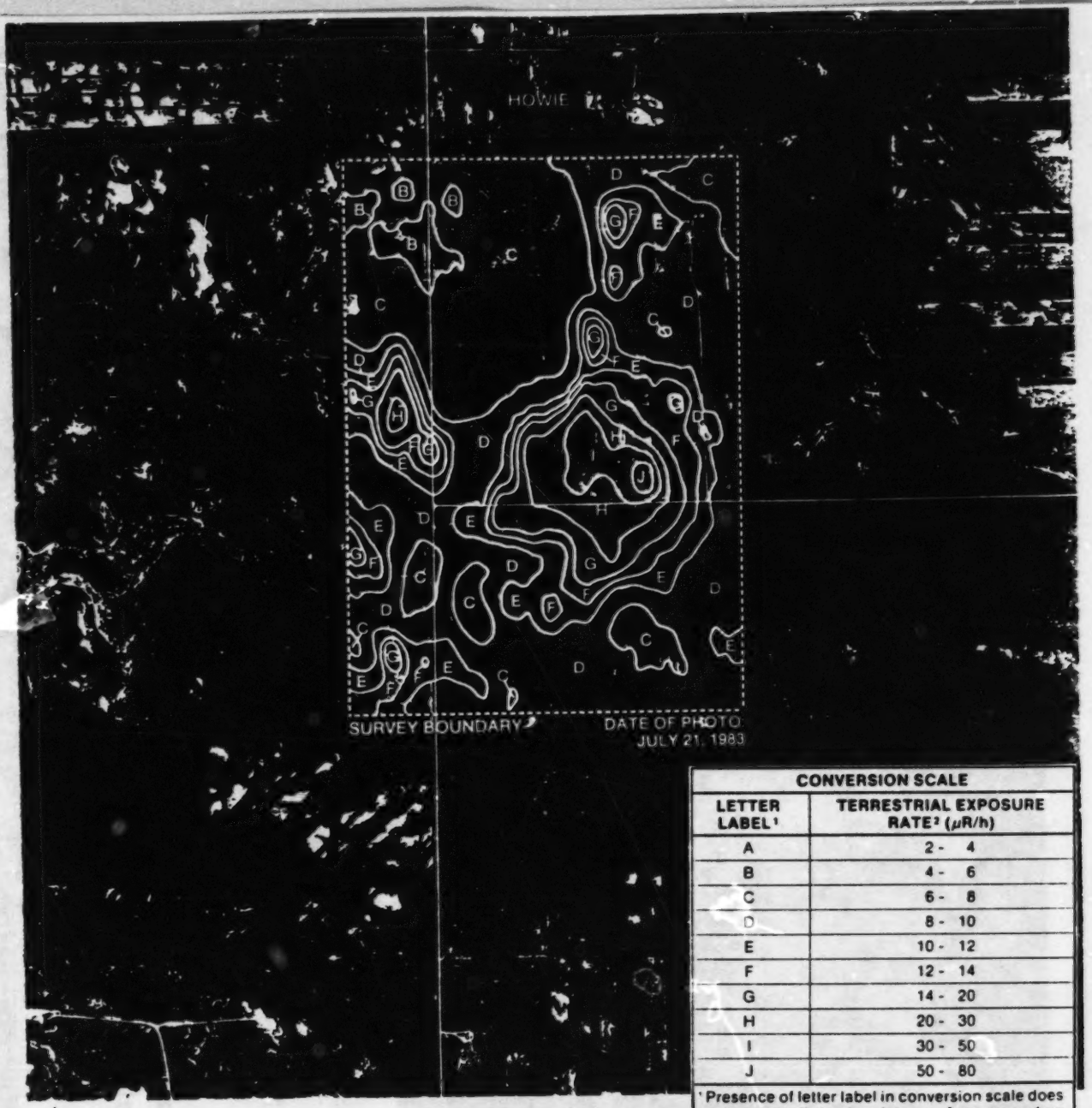
N

0 1000 2000 3000 FEET

0 200 400 600 800 1000 METERS

ISORADIATION CONTOURS OF TERRESTRIAL GAMMA RAY EXPOSURE RATE SUPERIMPOSED ON AN AERIAL PHOTOGRAPH OF THE KLYM URANIFEROUS LIGNITE MINE SITE NEAR BELFIELD, NORTH DAKOTA (T142-R99-S26)

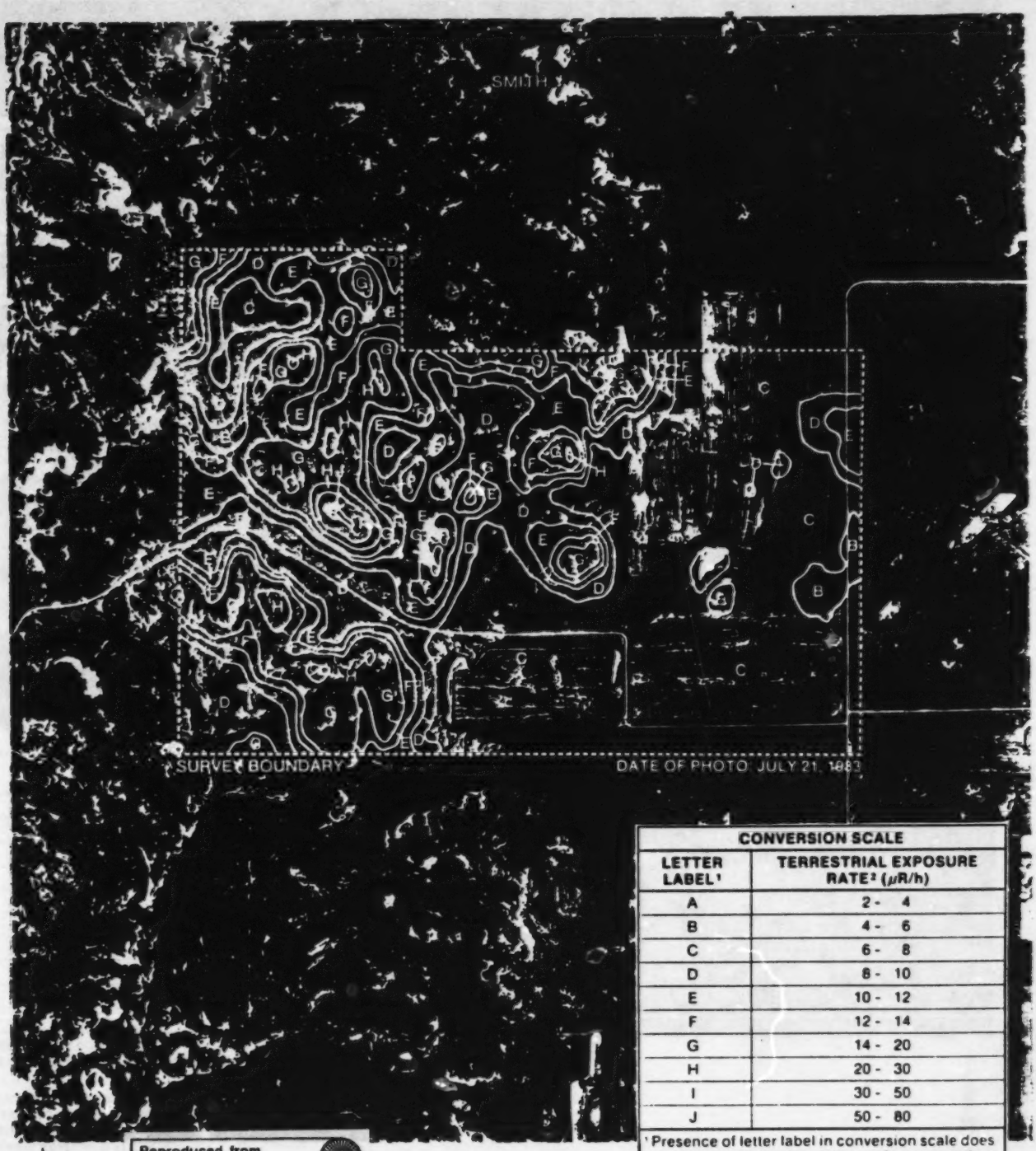


CONVERSION SCALE	
LETTER LABEL[1]	TERRESTRIAL EXPOSURE RATE[2] (μR/h)
A	2 - 4
B	4 - 6
C	6 - 8
D	8 - 10
E	10 - 12
F	12 - 14
G	14 - 20
H	20 - 30
I	30 - 50
J	50 - 80

[1] Presence of letter label in conversion scale does not necessarily imply existence of corresponding contour interval in plot.

[2] Contours indicate gamma exposure rate extrapolated to 1 m above the ground, inferred from gamma count rate observed at 75 ft above the ground. Extrapolation valid only over large areas comparable to the detector's field-of-view. Cosmic rays contribute an additional 4.4 μR/h to the reported values.

ISORADIATION CONTOURS OF TERRESTRIAL GAMMA RAY EXPOSURE RATE SUPERIMPOSED ON AN AERIAL PHOTOGRAPH OF THE HOWIE URANIFEROUS LIGNITE MINE SITE NEAR BELFIELD, NORTH DAKOTA (T137-R100-S2)



CONVERSION SCALE	
LETTER LABEL[1]	TERRESTRIAL EXPOSURE RATE[2] (μR/h)
A	2 - 4
B	4 - 6
C	6 - 8
D	8 - 10
E	10 - 12
F	12 - 14
G	14 - 20
H	20 - 30
I	30 - 50
J	50 - 80

[1] Presence of letter label in conversion scale does not necessarily imply existence of corresponding contour interval in plot.

[2] Contours indicate gamma exposure rate extrapolated to 1 m above the ground, inferred from gamma count rate observed at 75 ft above the ground. Extrapolation valid only over large areas comparable to the detector's field-of-view. Cosmic rays contribute an additional 4.4 μR/h to the reported values.

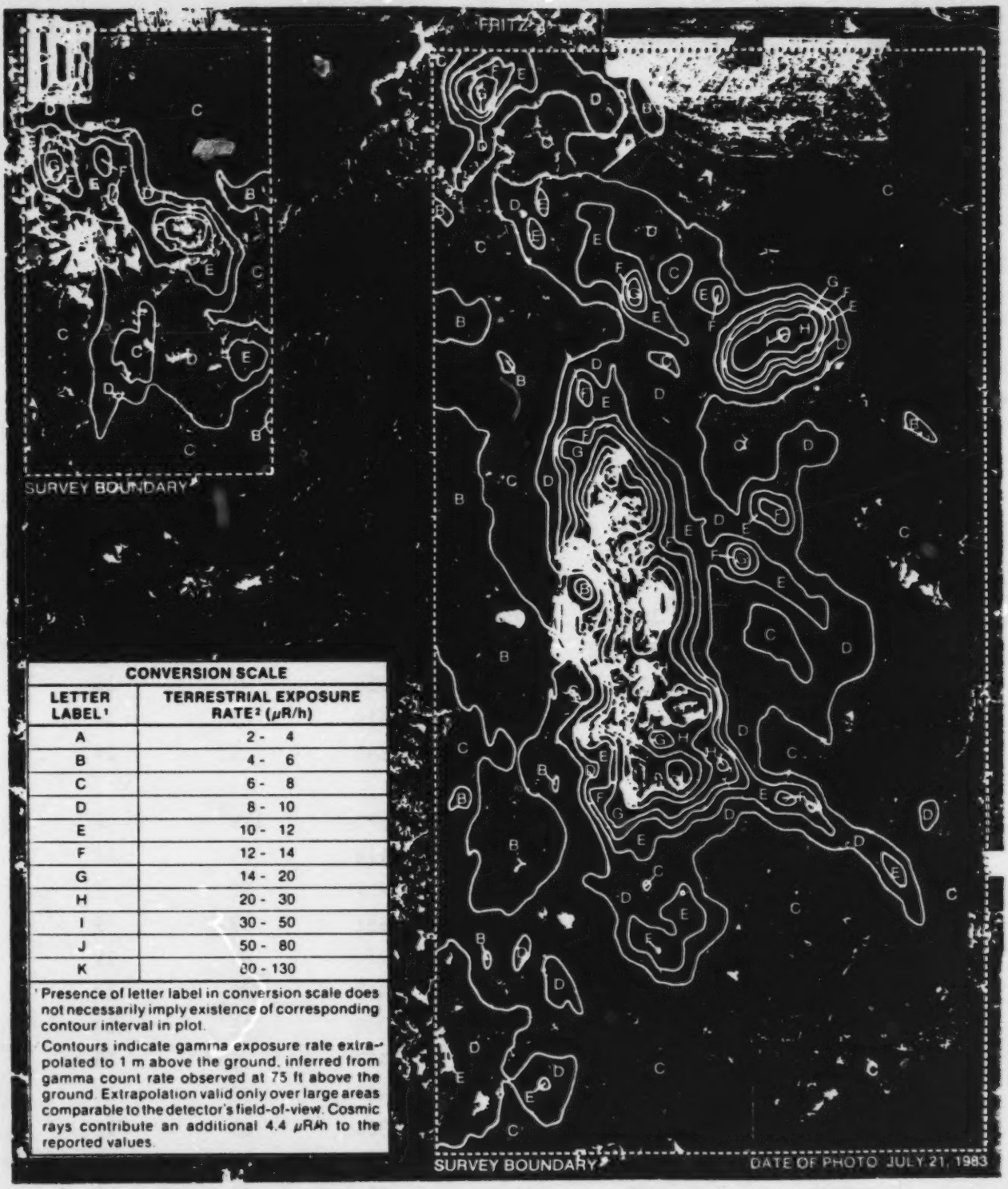
Reproduced from best available copy.

N

0 1000 2000 3000 FEET

0 200 400 600 800 1000 METERS

ISORADIATION CONTOURS OF TERRESTRIAL GAMMA RAY EXPOSURE RATE SUPERIMPOSED ON AN AERIAL PHOTOGRAPH OF THE SMITH URANIFEROUS LIGNITE MINE SITE NEAR BELFIELD, NORTH DAKOTA (T137-R100-S5)



CONVERSION SCALE	
LETTER LABEL[1]	TERRESTRIAL EXPOSURE RATE[2] (μR/h)
A	2 - 4
B	4 - 6
C	6 - 8
D	8 - 10
E	10 - 12
F	12 - 14
G	14 - 20
H	20 - 30
I	30 - 50
J	50 - 80
K	80 - 130

[1] Presence of letter label in conversion scale does not necessarily imply existence of corresponding contour interval in plot.

[2] Contours indicate gamma exposure rate extrapolated to 1 m above the ground, inferred from gamma count rate observed at 75 ft above the ground. Extrapolation valid only over large areas comparable to the detector's field-of-view. Cosmic rays contribute an additional 4.4 μR/h to the reported values.

0 1000 2000 3000 FEET
0 200 400 600 800 1000 METERS

N

ISORADIATION CONTOURS OF TERRESTRIAL GAMMA RAY EXPOSURE RATE SUPERIMPOSED ON AN AERIAL PHOTOGRAPH OF THE FRITZ URANIFEROUS LIGNITE MINE SITE NEAR BELFIELD, NORTH DAKOTA (T136-R100-S5)

APPENDIX B

ACID EXTRACTABLE METALS
(µg metal/g dry soil)

Mine Site and Radial No.	As	Mg	Mn	Mo	Pb
Frank A					
020000	169	4900	289	26	12
060002	106	5950	1460	3	21
Frank B					
020000	99	4240	936	24	17
020002	119	4700	1190	30	18
020004	96	4230	1090	4	15
020005	101	4360	1070	<1	18
040000	502	7920	408	722	28
040001	58	4780	3250	<1	15
040003	72	5260	1610	1	12
040006	102	8860	1040	7	24
Howie					
010000	45	1920	175	119	6
020002	98	3730	174	81	13
020004	49	2460	227	50	7
020006	78	4580	551	39	9
020008	67	3500	474	64	12
020010	71	3790	452	32	12
020012	47	3070	369	15	10
020014	67	4550	467	5	16
040002	83	3840	427	82	12
040004	79	4280	366	66	11
040006	59	4200	893	10	17
040007	72	3390	475	16	13
040008	73	3720	402	3	13

Acid Extractable Metals (continued)

Mine Site and Radial No.	As	Mg	Mn	Mo	Pb
Fritz					
040000	68	3680	661	24	13
040001	117	8000	982	11	21
040002	63	3390	773	17	10
060000	68	3000	110	116	11
060002	75	4000	554	27	14
060005	81	3840	522	7	17
Palaniuk A					
020000	69	2230	225	31	7
020001	102	4160	808	18	15
Palaniuk B					
020001	69	4070	583	13	14
050000	38	2350	417	6	8
Palaniuk C					
030000	64	3870	511	11	10
030001	120	4960	810	80	15
040001	77	3690	371	29	14
Palaniuk D					
010000	94	3260	373	132	14
040000	87	4410	386	7	10
Smith A					
060000	121	2440	126	344	21
060006	61	4070	365	9	16
Smith B					
010000	22	2300	199	3	4
020000	69	4000	433	3	13
030000	71	4700	218	7	13
040000	67	3660	498	3	13

Acid Extractable Metals (continued)

Mine Site and Radial No.	As	Mg	Mn	Mo	Pb
Talkington					
030000	74	4010	438	33	12
030002	63	4290	478	4	13
Klym					
060000	67	4260	928	15	18
150002	89	3870	1190	12	23

APPENDIX C

RADIUM-226 IN BACKGROUND SOIL SAMPLES

Mine Site and Radial No.	Scintillometer* at 3 ft. (μR/hr)	Scintillometer** at Ground (μR/hr)	Delta	Ra-226 (pCi/g Dry Soil)
Smith A				
020002	18	18	4.5	2.5
020003	16.5	17.5	4.5	2.8
030002	16	18	5	5.4
030003	13	15	4	4.4
040001	19	20	4	2.9
040002	15	16	4	2.2
050001	26	25	5	5.3
041005	17	17	5	3.1
011008	15	15	4	2.8
Smith B				
010000	10	10	3	1.8
010001	11	10	2	1.5
010002	10	12	4	1.8
010003	10	12	4	1.8
020000	9	10	1.5	2.1
020001	11	11	3	1.6
020002	10	10.5	3	1.8
030000	9	9	2	1.4
030001	9	9	1	1.8
040000	10	10	2	2.2
040004	10	10	1	2.2
Talkington				
010004	25	25	5	4.9
010005	21	20	4	5.9

Radium-226 in Background Soil Samples (continued)

Mine Site and Radial No.	Scintillometer* at 3 ft. (μR/hr)	Scintillometer** at Ground (μR/hr)	Delta	Ra-226 (pCi/g Dry Soil)
Talkington (continued)				
020001	25	24	5	6.0
020002	18	19	4.5	5.5
030002	15	17	4	6.4
040002	20	20	3	2.3
050003	23	23	5	4.1
064004	26	26	4	3.7
040007	17	17	3	1.8
071006	22	23	5	5.8
Frank A				
010003	19	20	5	9.7
020002	16.5	17.5	5	7.0
030001	22	22	4	4.7
030002	20	20	5	7.6
040002	18	18	5	3.3
061010	18	18	5	4.0
011016	18	19	4	5.9
Frank B				
010004	19	18	5	5.3
040006	16	17	5	3.9
031010	12	15	4	1.9
Palaniuk A				
010001	16	17	5	4.6
020003	21	20	5	5.3
030000	15	14	3	6.2
030001	13	13	3	2.6
040002	14	13.5	3.5	6.3
020001	18	18	4	3.7
041005	17	16	3	4.2
011001	21	21	4	4.4

Radium-226 in Background Soil Samples (continued)

Mine Site and Radial No.	Scintillometer* at 3 ft. (μR/hr)	Scintillometer** at Ground (μR/hr)	Delta	Ra-226 (pCi/g Dry Soil)
Palaniuk B				
030000	17.5	18.5	5.5	7.2
030001	16	16	3	5.4
040002	30	28	3	6.8
050001	31	28	5	4.6
070000	15	15	1	6.6
080000	28	22	4	8.6
Palaniuk C				
010000	12	12	4	2.4
020000	10	11	2	2.4
Palaniuk D				
020001	17	15	5	2.8
040000	18	17	5	3.8
021001	14	16	4	3.1
021002	13	14	2	2.9
031008	14	15	3	3.1
Klym				
010001	20	21	5	4.4
020000	26	23	5.5	5.9
020002	19	19.5	5.5	3.9
050001	19	19	4	4.3
060002	19	18	5	5.2
070000	14	13	3	2.9
080000	11	12	3	2.4
090000	13	13	4	2.9
100000	15	15	4	4.7
110000	17	16	4	6.9
120000	17	16	3	7.7
130000	19	19	5	8.3
140000	16	16	4	6.3

Radium-226 in Background Soil Samples (continued)

Mine Site and Radial No.	Scintillometer* at 3 ft. (μR/hr)	Scintillometer** at Ground (μR/hr)	Delta	Ra-226 (pCi/g Dry Soil)
Klym (continued)				
150001	22	22	5	7.6
160000	20	20	5	5.1
160001	20	20	5	3.6
151012	14	13	4	2.4
151007	21	22	3	7.7
021010	20	19	4	5.9
021005	22	23	3	9.6
Fritz				
020000	18	18	5	4.0
040002	23	23.5	4.5	5.9
050005	17	16.5	4	1.9
060005	19	19	5	3.9
070003	15	16	4	1.8
111007	14	13	1.5	1.3
121008	8	10	3	0.9
041003	23	24	2	4.5
041004	16	17	4	3.5
041005	17	17	4	4.1
051004	21	21	5	3.2
051005	18	20	5	5.5
Howie				
010010	17	17	4	2.5
010012	12	13	3	2.6
020014	20	20	5	3.9
040006	20	22	3	4.3
040008	20	20	5	4.5

* Scintillometer readings in μR/hr at 3 feet above the ground.
** Scintillometer readings in μR/hr at the surface of the ground.
*** The difference of the scintillometer-gr without a shield and scintillometer-gr with shield.

APPENDIX D

CORRELATION OF SCINTILLOMETER MEASUREMENTS WITH PIC READINGS

Mine Site and Radial No.	Scintillometer at 3 ft. (μR/hr)	PIC (μR/hr)
Howie		
010000*	55	27.78
010002	47	25.95
010004	40	20.37
010006	45	25.33
010008	60	32.76
010010	17	14.06
010012	12	12.57
020002	40	21.09
020004	48	25.75
020006	65	30.49
020008	150	73.5
020010	40	21.44
020012	28	15.87
020014	20	13.89
030002	43	24.94
030004	27	21.98
030006	20	16.4
030008	16	14.95
040000*	50	27.03
040002	50	27.94
040004	45	25.21
040006	20	13.52
040007	20	13.81
040008	20	14.47

* 040000 and 010000 are identical location.

Correlation of Scintillometer Measurements with PIC Readings (continued)

Mine Site and Radial No.	Scintillometer at 3 ft. (μR/hr)	PIC (μR/hr)
Smith A		
030000	29	21.05
030001	21	15.76
030002	16	14.17
030003	13	13.1
040000	50	31.02
040001	19	13.74
040002	15	12.56
Smith B		
030000	9	10.01
030001	9	10.12
040000	10	11.27
040004	10	11.37
Talkington		
040000	75	32.68
040001	25	14.3
040002	20	13.12
060000	60	31.26
060001	40	21.23
060002	35	19.8
060003	30	16.48
060004	26	16.13
Palaniuk A		
010000	30	20.3
010001	16	14.77
030000	15	13.74
030001	13	12.78

Correlation of Scintillometer Measurements with PIC Readings (continued)

Mine Site and Radial No.	Scintillometer at 3 ft. (μR/hr)	PIC (μR/hr)
Palaniuk B		
030000	17.5	15.86
030001	16	13.93
040000	37	18.77
040001	40	21.02
040002	30	16.43
050000	38	19.64
050001	31	15.75
050002	24	14.05
Palaniuk C		
010000	12	11.11
020000	10	11.39
030000	150	95.28
030001	60	28.18
Fritz		
040000	50	23.49
040001	43	21.74
040002	23	16.35
040003	20	14.22
050000	50	31.57
050001	38	20.12
050002	38	20.12
Klym		
010000	40	21.15
010001	20	14.13
020000	26	15.36
020001	20.5	14.42
020002	19	13.42
160000	20	13.19
160001	20	12.44

Correlation of Scintillometer Measurements with PIC Readings (continued)

Mine Site and Radial No.	Scintillometer at 3 ft. (μR/hr)	PIC (μR/hr)
Frank A		
030000	30	15.74
030001	22	14.39
030002	20	13.94
030003	14	13.34
040000	30	14.39
040001	32	18.98
040002	18	17.14
050000	32	19.64
050001	32	19.73
Frank B		
020000	62	31.19
020001	65	34.59
020002	60	30.48
020003	40	20.93
020004	40	20.15
020005	30	17.91

APPENDIX E

RA-226 ANALYSIS OF FRACTIONATED SAMPLES

Mine Site and Radial No.	Depth	Ra-226 (pCi/gm)
Smith A		
041000	0-5 cm	38.6
041000	5-10 cm	4.0
041000	10-15 cm	2.2
061000	0-5 cm	48.0
061000	5-10 cm	58.6
061000	10-15 cm	68.4
Talkington		
070000	0-5 cm	102.4
070000	5-10 cm	50.6
070000	10-15 cm	51.8
070001	0-5 cm	19.0
070001	5-10 cm	9.8
070001	10-15 cm	11.5
080000	0-5 cm	26.6
080000	5-10 cm	10.8
080000	10-15 cm	8.1
Palaniuk C		
030001	0-5 cm	27.3
030001	5-10 cm	15.2
030001	10-15 cm	4.8
040004	0-5 cm	10.7
040004	5-10 cm	11.5
040004	10-15 cm	18.7

Ra-226 Analysis of Fractionated Samples (continued)

Mine Site and Radial No.	Depth	Ra-226 (pCi/gm)
Palaniuk D		
010000	0-5 cm	33.4
010000	5-10 cm	6.0
010000	10-15 cm	3.2
020000	0-5 cm	13.4
020000	5-10 cm	9.5
020000	10-15 cm	14.9
020001	0-5 cm	3.1
020001	5-10 cm	2.9
020001	10-15 cm	3.0
021001	0-5 cm	3.1
021001	5-10 cm	3.0
021001	10-15 cm	3.2
021002	0-5 cm	2.9
021002	5-10 cm	2.6
021002	10-15 cm	2.6
Fritz		
041000	0-5 cm	22.2
041000	5-10 cm	3.1
041000	10-15 cm	3.4
041001	0-5 cm	5.7
041001	5-10 cm	5.6
041001	10-15 cm	8.1
041002	0-5 cm	14.4
041002	5-10 cm	6.1
041002	10-15 cm	5.0
041003	0-5 cm	5.2
041003	5-10 cm	3.9
041003	10-15 cm	4.5
041004	0-5 cm	6.7

Ra-226 Analysis of Fractionated Samples (continued)

Mine Site and Radial No.	Depth	Ra-226 (pCi/gm)
Fritz (continued)		
041004	5-10 cm	1.8
041004	10-15 cm	1.9
041005	0-5 cm	7.3
041005	5-10 cm	2.5
041005	10-15 cm	2.6
051000	0-5 cm	17.2
051000	5-10 cm	13.0
051000	10-15 cm	10.0
051001	0-5 cm	14.8
051001	5-10 cm	3.3
051001	10-15 cm	3.6
051002	0-5 cm	10.8
051002	5-10 cm	3.5
051002	10-15 cm	3.7
051003	0-5 cm	6.5
051003	5-10 cm	2.9
051003	10-15 cm	2.7
051004	0-5 cm	3.2
051004	5-10 cm	2.9
051004	10-15 cm	3.4
051005	0-5 cm	7.6
051005	5-10 cm	4.3
051005	10-15 cm	4.7

APPENDIX F

RADIUM-226 ANALYSIS

Mine Site and Radial No.	Scintillometer (μ/hr) 3 ft. (open)	Ground (open)	Delta	pCi/gram
Smith A				
010000	100	95	30	39.9
010001	30	32	10	6.9
010002	21	24	8	6.8
010003	24	27	9	10.0
010004	25	28	9	7.9
010005	22	21	6	6.3
020000	50	50	15	19.8
020001	24	24	6	7.8
030000	29	29	5	12.9
030001	21	22	6	7.8
040000	50	49	11	15.0
050000	55	55	15	16.2
060000	80	80	25	13.8
060001	42	45	15	14.8
060002	35	35	15	11.0
060003	35	34	13	15.8
060004	30	25	9	11.5
060005	24	26	10	10.8
060006	23	22	6	6.1
060007	24	27	7	8.8

Radium 226 Analysis (continued)

Mine Site and Radial No.	Scintillometer (μ/hr) 3 ft. (open)	Ground (open)	Delta	pCi/gram
Talkington				
010000	85	45	10	3.7
010001	35	35	7	2.4
010002	30	30	8	4.4
010003	28	28	6	7.0
020000	48	42	7	3.6
030000	75	85	22	12.1
030001	40	42	10	7.4
040000	75	80	30	46.5
040001	25	27	6	2.9
050000	70	60	15	25.3
050001	50	48	13	8.1
050002	28	29	8	2.9
060000	60	70	20	21.2
060001	40	40	5	5.3
060002	35	35	7	6.3
060003	30	30	5	6.4
Frank A				
010000	42	38	9	15.6
010001	34	34	6	13.7
010002	29	30	8	9.8
020000	68	68	23	32.1
020001	19	19	6	7.5
030000	30	30	10	7.5
040000	30	30	10	9.0
040001	32	35	15	9.3
050000	32	32	5	12.0
050001	32	32	5	17.0
060000	50	57	15	22.2

Radium 226 Analysis (continued)

Mine Site and Radial No.	Scintillometer (μ/hr) 3 ft. (open)	Ground (open)	Delta	pCi/gram
Frank A (continued)				
060001	37	40	10	16.0
010002	32	33	6	10.9
Frank B				
010000	60	60	15	12.5
010001	45	40	10	12.7
010002	27	27	7	12.7
010003	23	24	7	9.8
020000	62	64	16	10.9
020001	65	65	15	29.0
020002	60	62	15	38.0
020003	40	40	10	14.6
020004	40	40	10	13.2
020005	30	30	5	10.4
030000	72	70	15	29.7
030001	46	50	10	10.3
030002	36	38	10	7.7
030003	28	29	07	3.6
030004	25	28	08	5.1
040000	300	450	200	264.5
040001	85	75	20	17.6
040002	60	50	11.5	17.7
040003	45	40	10	18.3
040004	35	35	8	8.9
040005	30	20	6	5.5
Palaniuk A				
010000	30	30	5	12.7
020000	60	60	20	24.2
020001	35	35	10	9.4

Radium 226 Analysis (continued)

Mine Site and Radial No.	Scintillometer (μ/hr) 3 ft. (open)	Ground (open)	Delta	pCi/gram
Palaniuk A (continued)				
020002	28	29	9	7.7
040000	70	60	15	12.7
040001	19	19	7	7.5
Palaniuk B				
010000	70	51	11	10.7
010001	38	38	8	7.8
010002	30	30	6	11.5
020000	55	55	15	6.2
020001	40	40	10	6.6
020002	32	31	5	3.7
040000	37	34	6	6.4
040001	40	38	3	7.5
050000	38	36	6	11.7
050002	24	24	6	3.1
060000	22	24	6	3.5
Klym				
010000	40	50	20	26.6
030000	42	40	10	10.8
030001	18	26	7	5.8
030002	23	23	6	5.1
040000	42	42	10	17.8
040002	25	26	7	7.4
040004	27	28	9	10.8
040006	38	40	12	23.0
040008	24	24	7	15.3
050000	45	41	12	30.1
050005	20	22	6	8.9
050007	28	30	11	17.9

Radium 226 Analysis (continued)

Mine Site and Radial No.	Scintillometer (μ/hr) 3 ft. (open)	Ground (open)	Delta	pCi/gram
Klym				
060000	35	35	10	14.5
060001	25	24	7	7.9
150000	28	25	6	11.8
Fritz				
010000	30	30	8	8.1
010001	23	23	6	1.4
030000	75	70	20	22.5
030001	45	45	10	12.8
040000	50	45	7	6.1
040001	43	45	12	19.2
050000	50	50	15	14.9
050001	38	40	12	9.6
050002	--	45	13	10.8
050003	30	23	6	6.2
060000	50	55	17	11.6
060001	29	30	6	10.8
060002	29	29	8	7.6
060003	23	23	7	3.5
070000	150	175	80	70.5
070001	22.5	23.5	6	3.7
080000	60	50	10	3.3
080001	45	50	12	4.1
080003	23	24	7	6.7
090000	50	50	15	8.8
090001	30	30	8	4.4
090003	25	23	8	7.9
090004	20	23	6	14.1
150000	15	16	6	2.0
160000	31	32	9	3.3